SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

The JOURNAL of the FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Special Features

Literature Review on Viability of Organisms—FSWA Research Committee

Successful Sewage Works Service—Hepler

pH Measurement and Control—Greer

Formaldehyde Oxidation—Gellman and Heukelekian

Analysis of B.O.D. Data—Moore, Thomas and Snow

OCTOBER, 1950—VOL. 22, No. 10

Now available . . .

TWENTY-YEAR INDEX

SEWAGE WORKS JOURNAL

1928—1948

AUTHORS • SUBJECTS • GEOGRAPHICAL

Here is the key to the great reservoir of fundamental knowledge that is stored in the 115 numbers of the JOURNAL that record the era of greatest progress in water pollution control. Almost 9000 entries are compiled and arranged for finger-tip location with maximum convenience and economy of time. Covers completely the entire content of the first twenty volumes of the JOURNAL. Bound in buckram, 144 pages.

Price — $4.50

Order your copy now from

THE GARRARD PRESS

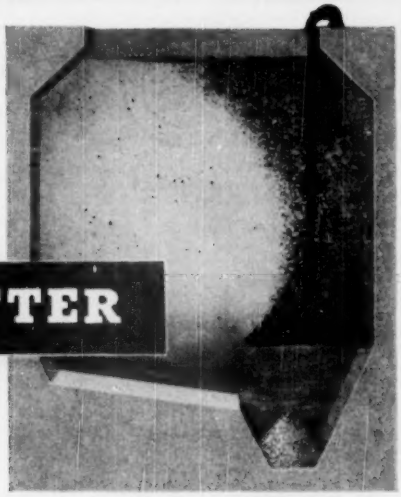
119 W. PARK AVE.

CHAMPAIGN, ILLINOIS

MAXIMUM REMOVAL

CLEAN GRIT

NO MECHANISMS



Chicago

AER-DEGRITTER

AIR CONTROLLED VELOCITIES

INDEPENDENT OF FLOW

LOW COST

SIMPLE STRUCTURE

The 'Chicago' Aer-Degritter now provides the only method of removing grit and sand from sewage without movable mechanical equipment. Air introduced through 'Chicago' Swing Diffusers and Precision Diffuser Tubes controls the velocity of the flow. All sand of 0.2 mm. (65 mesh) and larger is washed and deposited in a hopper at the bottom of the tank.

Analysis of grit removed by this system shows less than 10% volatile matter and only a negligible trace of putrescible organics. Because coarse sewage material will not interfere with the operation of the Aer-Degritter and because it does not affect the hydraulic design of the plant, Aer-Degritters may be installed ahead of all mechanical equipment.

'Chicago' Aer-Degritters have been operating successfully at Oildale, California; Columbus, Ohio; Tomah, Wisconsin; and Bellaire, Texas. Additional Aer-Degritters are being installed in Sedalia, Missouri; Ann Arbor, Michigan; Jasper, Indiana; and Fort St. John, B. C., Canada.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

2300 WOLFRAM STREET — **CHICAGO 18, ILLINOIS**

Flush Kleen, Screw-Feller, Plunger, Horizontal and Vertical Non-Clogs Water Seal Pumping Units. Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

PRESIDENT

A. H. NILES
Engineer-Superintendent
Division of Sewage Disposal
Bay View Park
Toledo 11, Ohio

VICE-PRESIDENT

RALPH E. FUHRMAN, Supt.
District of Columbia Sewage Treatment Plant
5000 Overlook Ave., S.W.
Washington 20, D. C.

TREASURER

W. W. DEBERARD
City Engineer
402 City Hall
Chicago, Illinois

EXECUTIVE SECRETARY-EDITOR

W. H. WISELY
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. MOHLMAN
Director of Laboratories
The Sanitary District of Chicago
910 S. Michigan Ave.
Chicago, Illinois

DIRECTORS

Alabama: R. C. BARTON (1951)
Argentina: E. B. BESSERLIEVRE (1943)*
Arizona: HAROLD YOST (1952)
Arkansas: B. W. DEES (1952)
California: RICHARD D. POMEROY (1950)
Canada: WILLIAM STORRIE (1952)
Central States: GEORGE MARTIN (1951)
Dakota: JOHN KLEVEN (1952)
Federal: LAWRENCE M. FISHER (1950)
Florida: B. F. BORDEN (1950)
Georgia: GILBERT R. FRITH (1950)
Inst. San. Eng. (Eng.): G. S. MCDONALD (1950)
Inst. Sew. Pur. (Eng.): W. F. FREEBORN (1950)
Iowa: JOHN L. STRELOW (1950)
Kansas: E. F. MILTNER (1951)
Kentucky-Tennessee: MAURICE L. MILLER (1952)
Louisiana: S. S. CRAWFORD (1952)
Maryland-Delaware: C. E. KEEPER (1951)
Michigan: L. F. ORMING (1952)
Missouri: A. H. WYMORE (1951)
Montana: K. L. CHRYSLER (1950)
New England: F. L. FLOOD (1951)
New Jersey: L. J. FONTENELLI (1951)
New York: G. E. SYMONS (1951)
North Carolina: R. S. PHILLIPS (1952)
Ohio: B. M. MCDILL (1951)
Oklahoma: FRANK S. TAYLOR (1950)
Pacific Northwest: C. M. HOWARD (1950)
Pennsylvania: C. H. YOUNG (1952)
Puerto Rico: ALBERTO HERNANDEZ (1950)
Rocky Mountain: L. O. WILLIAMS (1951)
South Carolina: GEORGE A. RHAME (1952)
Switzerland: W. DARDEL (1951)
Texas: J. H. SORRELLS (1951)
Virginia: L. L. HEDGEPETH (1950)
West Virginia: K. S. WATSON (1950)
At Large: R. H. GOULD (1952)
At Large: DON E. BLOODGOOD (1950)
At Large: CARL E. GREEN (1951)
W. and S. Wks. Mfgrs.: R. S. RANKIN (1950)
W. and S. Wks. Mfgrs.: W. A. HARDENBERGH (1951)
W. and S. Wks. Mfgrs.: HARRY E. SCHLENZ (1952)
Ex-Officio: V. M. EHLERS
Ex-Officio: M. M. COHN
Ex-Officio: EARNEST BOYCE
Ex-Officio: F. W. GILCREAS
Ex-Officio: WILLEM RUDOLFS
Ex-Officio: W. J. ORCHARD
* Successor not yet designated.

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States, $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

MAILING PERMIT

Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE

Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

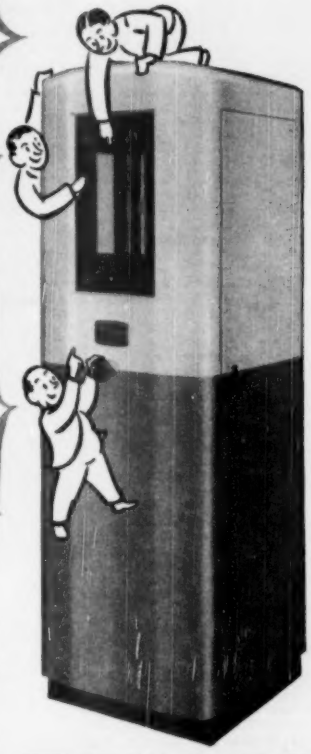
Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

See the flow!

Know the flow!

VISIBLE CHLORINE FLOW!

BUILDERS *Chlorinizers*



BUILDERS CHLORINIZER incorporates a true flow indicator — the SIGHTFLO indicator which measures ALL chlorine passing through the Chlorinizer and shows you the ACTUAL rate of chlorine feed on a direct-reading linear scale. Flow is indicated positively and accurately *only* when there is flow. It's another important feature of Builders Chlorinizer. For engineering information and Bulletins, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 368 Harris Ave., Providence 1, Rhode Island.

Installation at Gardner, Mass.

BUILDERS PRODUCTS: The Venturi Meter • Propelofio and Orifice Meters • Kennison Nozzles • Venturi Filter Controllers and Gauges • Conveyofio Meters Type M and Flo-Watch Instruments • Wheeler Filter Bottoms • Master Controllers • Chlorinizers — Chlorine Gas Feeders • Filter Operating Tables • Manometers Chronofio Telemeters

BUILDERS PROVIDENCE *Instruments*

FSWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
ALEX O. TAYLOR, *Secretary*
Box 69
Alabama Polytechnic Institute
Auburn, Alabama

Argentina Society of Engineers, Sanitary Engineering Div.
EDMUND B. BESSELIEVRE, *FSWA Contact Member*
c/o The Dorr Company
Barry Place
Stamford, Conn.

Arizona Sewage and Water Works Assn.*
MRS. HELEN ROTTHAUS, *Sec.-Treas.*
c/o Sanitary Engineering Div.
Arizona State Dept. of Health
Capitol Building
Phoenix, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
118 Chemistry Bldg.
Fayetteville, Ark.

California Sewage Works Assn.
DR. LAWRENCE H. COOK, *Sec.-Treas.*
Box 696
Menlo Park, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Ontario Dept. of Health
Sanitary Engineering Div.
Toronto 8, Ontario, Canada

Central States Sewage Works Assn.
A. PAUL TROMPER, *Sec.-Treas.*
Div. of Sanitary Engineering
Illinois Dept. of Public Health
Springfield, Ill.

Dakota Water and Sewage Works Conf.

*North Dakota Section**
JEROME H. SVOBE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

*South Dakota Section**
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health
Pierre, S. Dak.

Federal Sewage Research Assn.
LEONARD B. DWORSKY, *Sec.-Treas.*
c/o Div. of Water Pollution Control
U. S. P. H. S.
Washington 25, D. C.

Florida Sewage Works Assn.
PERRY M. TREPLE, *Sec.-Treas.*
Florida State Board of Health
P. O. Box 210
Jacksonville, Fla.

Georgia Water and Sewage Assn.*
L. E. WALLER, *Sec.-Treas.*
Rte. 12, Box 246
Atlanta, Ga.

Iowa Sewage Works Assn.
LEO HOLTKAMP, *Sec.-Treas.*
E. Ohio St.
Webster City, Iowa

Institute of Sewage Purification
MARTIN LOVETT, *FSWA Contact Member*
206 Bradford Rd.
Wakefield, Yorks., England

Institution of Sanitary Engineers
ERNEST BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1
London, England

Kansas Sewage Works Assn.
DWIGHT F. METZLER, *Sec.-Treas.*
c/o State Board of Health
Marvin Hall
University of Kansas
Lawrence, Kans.

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
R. PAUL FARRELL, *Sec.-Treas.*
420 Sixth Ave., N.
Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
S. V. HAZLIP, *Sec.-Treas.*
Water and Sewerage Dept.
Houma, La.

Maryland-Delaware Water and Sewerage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St.
Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334 Administration Bldg.
Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg.
Jefferson City, Mo.

Montana Sewage Works Assn.
H. B. FOOTE, *Sec.-Treas.*
Div. of Sanitary Engineering
State Board of Health
Helena, Montana

New England Sewage Works Assn.
WALTER E. MERRILL, *Sec.-Treas.*
c/o State Dept. of Health
511-A State House
Boston, Mass.

New Jersey Sewage and Industrial Wastes Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 766
Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C. SWEENEY, *Secretary*
c/o State Dept. of Health
21 N. Broadway
White Plains, N. Y.

North Carolina Sewage Works Assn.
E. C. HUBBARD, *Sec.-Treas.*
North Carolina State Board of Health
Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
J. E. RICHARDS, *Acting Sec.-Treas.*
301 Ohio Depts. Bldg.
Columbus 15, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
H. J. DARCEY, *Sec.-Treas.*
State Dept. of Health
Oklahoma City 5, Okla.

Pacific Northwest Sewage Works Assn.
ROBERT E. LEAVER, *Sec.-Treas.*
Dept. of Health
Smith Tower
Seattle 4, Wash.

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center
Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ALVAH R. PIERCE, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832
San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
CARROLL H. COBERLY, *Sec.-Treas.*
Room 329
1441 Welton St.
Denver 2, Colo.

South Carolina Water and Sewage Works Assn.*
W. T. LINTON, *Sec.-Treas.*
Wade Hampton Bldg.
Columbia, S. C.

Swiss Assn. of Water and Sewage Professionals
WALTER DARDEL, *FSWA Contact Member*
Aarberg (Berne), Switz.

Texas Water and Sewage Works Assn.
V. M. EHLERS, *Sec.-Treas.*
501 W. 33rd St.
Austin, Tex.

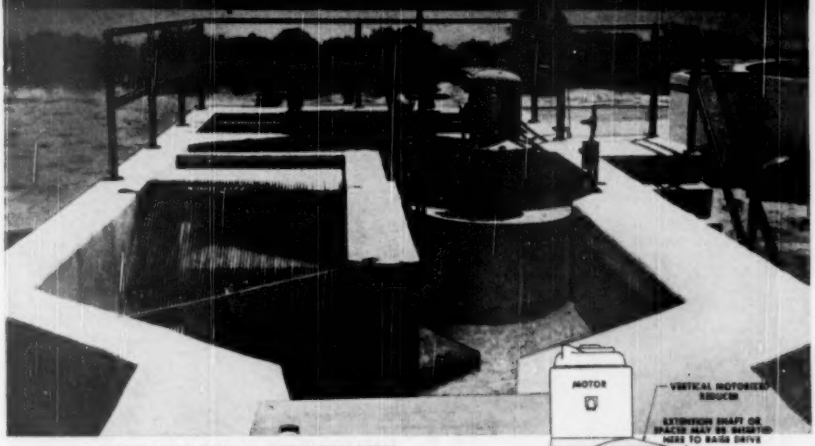
Virginia Industrial Wastes and Sewage Works Assn.
W. L. SCOTT, *Sec.-Treas.*
c/o State Water Control Board
815 E. Franklin St.
Richmond 19, Va.

West Virginia Sewage and Industrial Wastes Assn.
R. G. MCCALL, *Sec.-Treas.*
Room 643, State Capitol Bldg.
Charleston, W. Va.

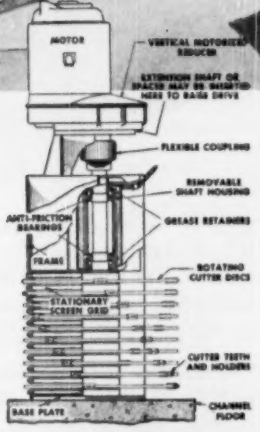
* Sewage Works Section.

GRIDUCTOR

STRAIGHT CHANNEL SEWAGE SCREENING AND CUTTING



GRIDUCTOR INSTALLATION (Size 36), DAYTONA BEACH, FLORIDA



Combines Coarse and Fine Screening Actions with Cutting and Shearing

HERE'S a *better* way to reduce the size of solids! GRIDUCTOR does it by intermittent cutting and shearing without excessively increasing the dissolved organic content of the sewage. Easily and quickly installed in new or existing sewage screen channels. Protects treatment plant units from fouling and clogging. Delivers more readily settleable solids to primary clarifier, and larger quantity of sludge to digester increasing gas production. Get all the facts about this sturdy, efficient equipment. Send for Bulletin No. 5100. Write today . . or, ask our nearest field engineer for complete information.

INFILCO

• BETTER WATER CONDITIONING • AND WASTE TREATMENT SINCE 1894

INFILCO INC.

SALES OFFICES IN TWENTY SIX PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

Memphis uses economical

CONCRETE PIPE

to drain Municipal Airport

SINCE 1929, Memphis has expanded its Municipal Airport from 200 to 850 acres. Passenger traffic has increased from 38,000 in 1938 to 400,000 in 1948.

The latest development consists of (1) a 230 ft. extension of two existing 108-in. parallel concrete pipe lines and (2) a third 108-in. concrete pipe line paralleling the entire 760 ft. length of the first two.

This triple barrel concrete drainage line will carry the flow of Hurricane Creek under a new extension of the east-west runway. The 108-in. reinforced concrete pipe is extra strength, manufactured under ASTM specifications C76-41. Walls are 9 in. thick.

Concrete pipe lines in the Memphis Airport's vast drainage system now range in size from 6 in. (for subdrainage under runways) to 108 in. and can handle as much as 2 in. of rainfall per hour.

Concrete pipe storm sewers provide economical drainage year after year because their first cost is moderate, they require little or no maintenance and have extra long life. This results in dependable *low-annual-cost* service.

AMERICAN CONCRETE PIPE ASSOCIATION

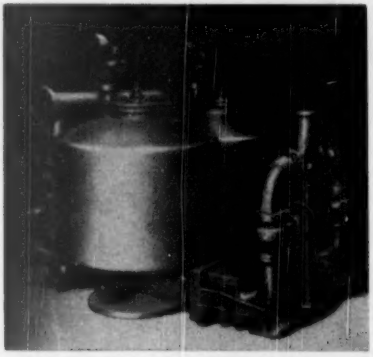
228 NORTH LA SALLE STREET, CHICAGO 1, ILLINOIS

Good reasons why they are your best buy

FOR EVERY MUNICIPAL INSTALLATION

SHONE® PNEUMATIC EJECTORS

FOR HANDLING CRUDE SEWAGE AND SLUDGE IN SEWAGE LIFT STATIONS • IN SUBWAYS • IN MUNICIPAL SEWAGE PLANTS



These far-sighted communities wanted the best, chose Shone Ejectors for recent installations:

Daytona Beach, Fla. (6)
Los Angeles, Calif., Hyperion Treatment Plant (2)
Campus, University of Washington, Seattle (2)
Chicago, Ill., West Side Subway Extension (22)
Osceola, Iowa
Mt. Clemens, Mich.
Freeport, L. I., New York (6)
Port Washington, L. I., New York (2)
Moorehead, Minn., Treatment Plant (6)
Anacostia Treatment Plant, Washington, D. C.

A few of hundreds of older Shones operating as efficiently and dependably as ever:

Long Beach, Calif.	Winona, Minn.
Ft. Lauderdale, Fla.	Brookhaven, Miss.
Pensacola, Fla.	Butler, Mo.
Silver Springs, Fla.	Rolla, Mo.
Dublin, Ga.	Bloomfield, Nebr.
LaPorte, Ind.	Manchester, N. H.
Warsaw, Ind.	Auburn, N. Y.
Cedar Rapids, Ia.	Olean, N. Y.
Davenport, Ia.	Rochester, N. Y.
Sioux City, Ia.	Berea, O.
Hays, Kans.	Dayton, O.
Salina, Kans.	Enid, Okla.
Winnsboro, La.	Tulsa, Okla.
Aberdeen, Md.	Providence, R. I.
Baltimore, Md.	Memphis, Tenn.
Brighton, Mich.	Austin, Tex.
Detroit, Mich.	Dallas, Tex.
Flint, Mich.	Madison, Wis.
Pontiac, Mich.	Milwaukee, Wis.
Royal Oak, Mich.	Neenah, Wis.
Tawas City, Mich.	Laramie, Wyo.
Faribault, Minn.	

√ no wet well

√ no noxious fumes or odors

√ no danger of explosion

√ no screens or shredders -- no repulsive cleaning job

For 75 years, in hundreds of municipal installations around the world, Shone Pneumatic Ejectors have been a symbol of utter dependability.

You may have heard the amazing story of the Shone Ejector sealed in its pit for more than 20 years—never inspected because it was not listed among mechanical equipment; rediscovered when alteration work opened the pit—operating as rhythmically and quietly as the day it was installed.

MINIMUM MAINTENANCE

Shone Ejectors require *no attention*. They can be operated from distant compressors—and several can be operated from a single compressor plant.

Write for Bulletin 4004—contains Air Volume and Pressure Table, sizes, dimensions, air piping layouts and other comprehensive specifications. Use the coupon—for convenience.

YEOMANS

PUMPS FOR BUILDINGS, MUNICIPALITIES, INDUSTRIAL APPLICATIONS and a complete line of Sewage and Waste Treatment Equipment

YEOMANS BROTHERS COMPANY
1411 North Dayton Street, Chicago 22, Illinois

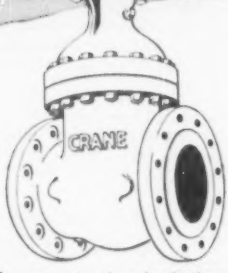
Please send your Bulletin 4004

Name .....
Company .....
Address .....
City ..... State .....

More **CRANE VALVES** are used than any other make

How CRANE controls quality to the Micro-Inch to cut your valve costs

Surface finish of a valve's working parts has a lot to do with its wear resistance and operating efficiency. A correct finish means a tighter-seating valve, easier operation, greater ease of maintenance. In Crane Quality valves, the surface finish of machined parts is measured and controlled to rigid limits. The standards for quality control of surface finish are determined by the most scientific methods as shown above. Yes, nothing is overlooked to make Crane Valves the lowest-cost valves in the long run. *That's Crane Quality!*



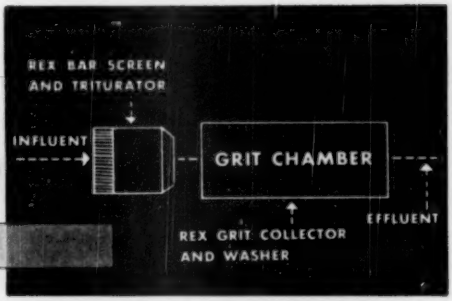
The lowest cost valves in the long run—Crane—because they're quality-controlled to industry's highest standards. For a sure remedy for high piping costs on steam, water, gas and other services, investigate Crane Steel Gate Valves. Contact your Crane Representative.

CRANE VALVES

CRANE CO., General Offices: 836 S. Michigan Ave., Chicago 5, Ill.

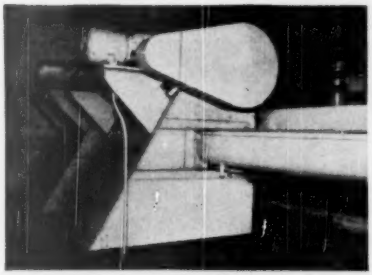
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



LINE-UP for EFFECTIVE SEPARATION

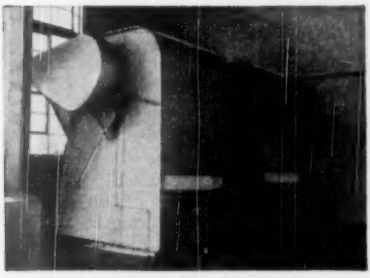
For most effective separation and removal of inorganic solids from liquids, rely on Rex Mechanically Cleaned Bar Screens and Rex Grit Collectors. At the Boat Harbor Sewage Treatment Plant in Newport News, for example, these efficient units are more than meeting the requirements. Two Rex type "MA" Bar Screens in channels 3′ wide x 15′ 6″ deep effectively remove large solids. The Rex Features . . . large bar rack area exposed to flow; straight, unobstructed flow; low head loss; large reserve capacity; rugged design; low installation and operating costs . . . assure maximum efficiency.



Rex V-Bucket Type Grit Collectors employing the Rex Recirculation Process for effective grit control at Boat Harbor Plant.

Material removed by the bar screens is ground to small size by Rex Triturators . . . the only screenings grinder that positively cuts material to bits by the shearing action of 2,000,000 blade cuts per minute. Ground material is returned to the liquid flow immediately behind the screen.

Two Rex V-Bucket Type Grit Collectors effectively separate and remove inorganic grit from the flow. Buckets carry and elevate the grit to a hopper which in turn feeds the grit into a cross screw conveyor. Conveyor discharges the grit into buckets for disposal. An important advantage of Rex Grit Collectors is their built-in recirculation process which provides effective control of grit quality. All grit is returned to the top of the incoming average or normal flow at the channel entrance. Organic material is thus carried out of the channel for further treatment . . . only concentrated grit resettles for disposal.



Rex Type MA Mechanically Cleaned Bar Screens equipped with Rex Triturators at Boat Harbor Plant.

Why not obtain these effective advantages for your plants? For all the facts, send for your copy of Bulletin No. 48-41. Chain Belt Company, 1606 W. Bruce Street, Milwaukee 4, Wisconsin.

CHAIN BELT REX COMPANY — SANITATION EQUIPMENT

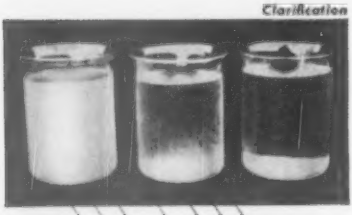
SEWAGE PLANT OPERATORS

For Clarification or Sludge Drying

INVESTIGATE THE ADVANTAGES

IN USING *GENERAL CHEMICAL* "ALUM"

Clarification



Above photograph illustrates effective coagulation and clarification of turbid waste by means of General Chemical Alum.

Clean and easy to handle

Dry feeds well or dissolves readily for solution feeding

Requires only low-cost feeding equipment and minimum attention

Helps sludge digest readily

Speeds sludge drying with minimum odor

Produces clear, low-color effluents

Reduces chlorine consumption in effluent

Economical to use

Sludge Drying

Above: Sludge bed treated with General Chemical Alum to hasten dewatering.

BASIC CHEMICALS

FOR AMERICAN INDUSTRY

Wherever your plant may be—America over—you will find General Chemical "Alum" is always the same high quality . . . always uniform . . . always readily available from coast-to-coast producing and shipping points. To you, that means increased efficiency, stepped-up economy in your clarification and sludge drying operations. So be sure. Get the best; specify General Chemical "Alum"—the *preferred* "Alum."

GENERAL CHEMICAL DIVISION

ALLIED CHEMICAL & DYE CORPORATION

40 Rector Street, New York 6, N. Y.

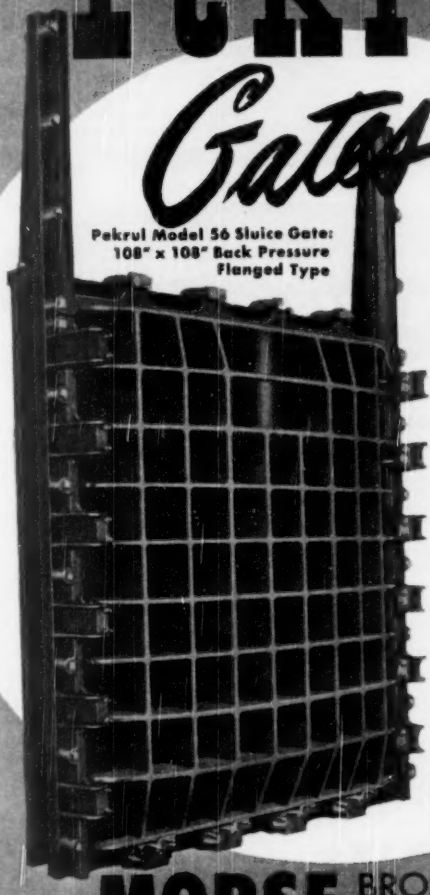
Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport Buffalo • Charlotte • Chicago • Cleveland • Denver • Detroit • Houston Jacksonville • Los Angeles • Minneapolis • New York • Philadelphia Pittsburgh • Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)

In Wisconsin: General Chemical Company, Inc., Milwaukee, Wis.

In Canada: The Nichols Chemical Company, Limited

Montreal • Toronto • Vancouver

Pekrul Gates



Pekrul Model 56 Sluice Gate:
108" x 108" Back Pressure
Flanged Type

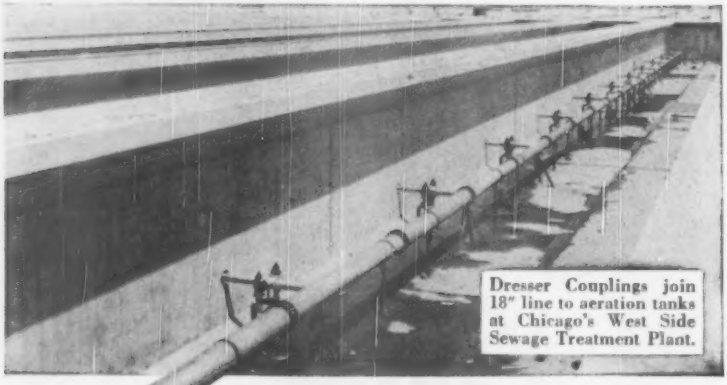
MANUFACTURERS OF
PEKRUL GATES FOR:

Flood Control
Levees
Irrigation
Water Works
Dams
Sewage Disposal
Reservoirs
Pumping Plants
Oil Refineries
Fish Hatcheries
Rearing Ponds
Recreation Pools
Cooling Towers

PEKRUL GATE DIVISION

MORSE BROS. MACHINERY
DENVER, COLORADO

Write for Catalog 49



it pays to join air lines
FLEXIBLE-TIGHT

Fourteen years of trouble-free service in Chicago's West Side Sewage Treatment Plant prove the dependability of Dresser Couplings for air distribution lines. These lines are continuing to give excellent service.

Lasting tightness is assured with Dressers, because these flexible joints, with their resilient rubber gaskets, harmlessly absorb vibration, expansion and contraction. Gaskets are specially compounded for long life.

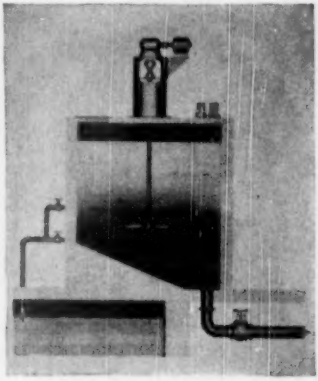
Ideal on raw-sewage, sludge, outfall, air, water-supply and inside pipe lines. Write today for catalog material.

DRESSER "FLEXIBLE-TIGHT" COUPLINGS

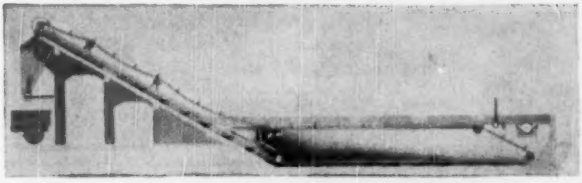
Dresser Manufacturing Division, 59 Fisher Avenue, Bradford, Pa. (One of the Dresser Industries). In Texas: 1121 Rothwell Street, Houston. In Canada: 629 Adelaide Street, W., Toronto. Sales Offices: New York, Philadelphia, Chicago, Houston, San Francisco.

Are INDUSTRIAL WASTES Your Problem?

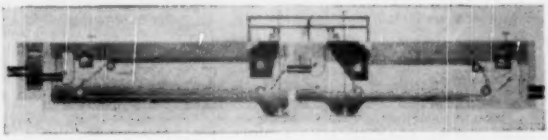
Let Link-Belt sanitary engineers show you how to recover valuable solids, protect public health, reduce stream pollution, and put waste treatment on an efficient basis. Link-Belt water and sewage treatment equipment is unexcelled in design and effective operation.



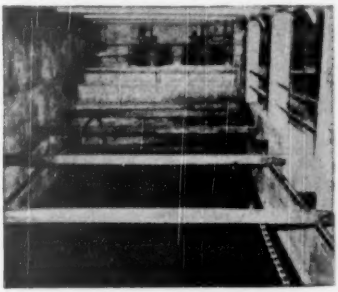
Above: Neutralization is accomplished by mixing lime with acid wastes in the Link-Belt Flash Mixer, which can also be used to treat metal plating wastes or wherever a rapid and thorough mixing of liquids and chemicals is desired.



Above: To prevent stream pollution, and recover valuable carbon, with low moisture content, and practically no hand labor, Link-Belt flight conveyor in a specially designed tank gives excellent results. Can also be used for removal of mill scale from cooling water, etc.



Above: To separate waste oil and heavy solids from refinery waste waters, Link-Belt Straightline oil and sludge collectors in specially designed tanks, give high efficiency, and conform to A.P.I. recommendations.



Above: Many Link-Belt Straightline sludge and grease collectors in catch basins at meat packing houses have paid their costs several times in value of grease and solids recovered. Grease is collected on water surface and solids are pushed along the floor of tank. Solids may be processed for protein animal food and grease recovered by rendering.

Link-Belt engineers have broad experience and a complete line of equipment—screens, sludge collectors, washers, mixers, dryers, aerators, power transmission and conveying machinery, with which to implement their recommendations.

11,512-A

LINK-BELT COMPANY

Philadelphia 40, Chicago 9, Indianapolis 6, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8. Offices in Principal Cities.

LINK-BELT

Sanitary Engineering Equipment

See General American for
CREATIVE FILTER ENGINEERING

For fast, continuous, automatic sludge dewatering . . . CONKEY SLUDGE FILTERS

Designed to do your job best!

Progressive sanitary engineers everywhere are finding Conkey Sludge Filters the better answer to their sludge dewatering problems. Superior drainage design, improved mechanical construction, advance selection of materials of fabrication are combined to assure performance on the job.

Custom-designed for the job to be done, Conkey Sludge Filters are built to handle the dewatering of these various types of sludge: primary directly handled *or* digested, *or* digested and elutriated, (activated with the same handling, chemical treatment or special process) and trade wastes of widely differing physical and chemical properties.

You can put undivided responsibility for your sludge filter installation in the hands of General American. Sludge filter stations, complete with necessary auxiliary equipment are supplied by us. Write for Bulletin No. 100.

Other General American Equipment:
Turbo-Mixers, Evaporators, Thickeners, Dewaterers, Dryers, Towers, Tanks, Bins, Pressure Vessels

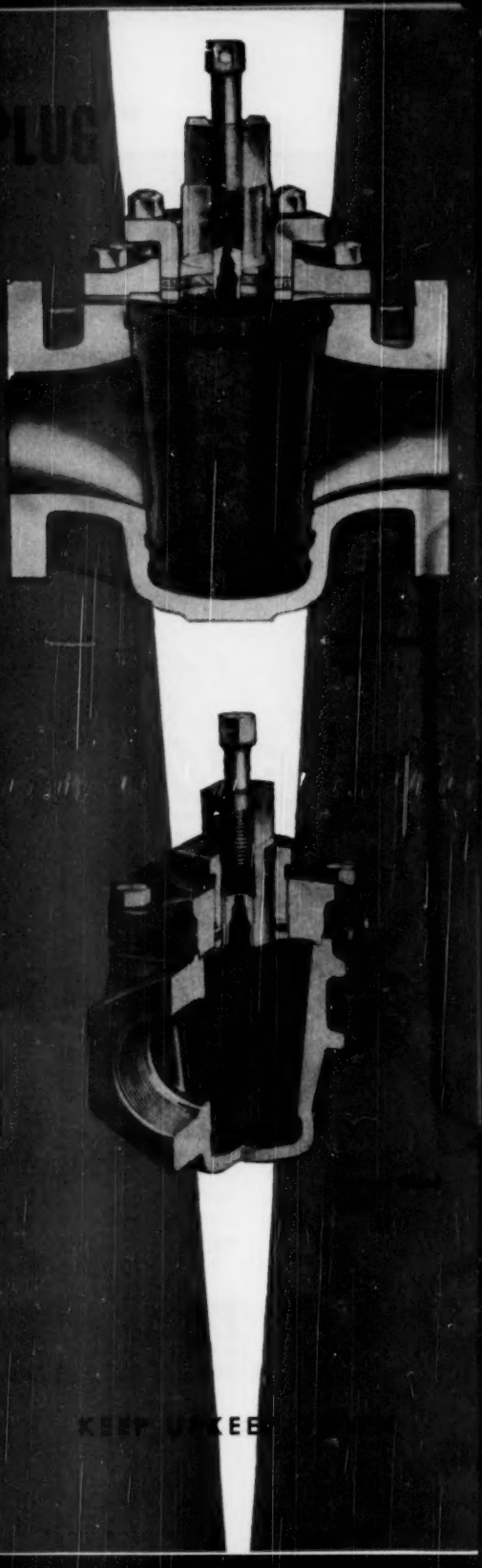
OFFICES IN ALL PRINCIPAL CITIES

Process Equipment Division
GENERAL AMERICAN
Transportation Corporation
Sales Offices: 10 E. 49th St., New York 17, N.Y.
General Offices: 135 S. La Salle St., Chicago 90, Ill.

It takes a TAPERED PLUG

to successfully handle

Sewage Sludge



TAPERED PLUG PREVENTS SEAT SEPARATION IN NORDSTROM VALVES

An exposed valve seat is subject to rapid wear. Grit grinds out the seat. Note how Nordstrom valves give full protection to the seat. Being tapered, the plug is always positively seated on a film of protective lubricant. A quarter turn fully closes or opens the valve. The plug can be jacked if ever too tight by turning the lubricant screw.

Kept sealed, automatically

"Sealdport" lubrication forms an effective leak-resistant seal around each port. Use of Rockwell Hypermatic lubricant *automatically* lubricates the valve, maintaining constant pressure within the valve so that frequent relubrication is unnecessary. Specify Nordstrom valves on all sludge lines, gas, air and water lines.

Grit cannot intrude. Plug seats on lubricant
"Sealdport" lubrication seals ports
Hypermatic automatically lubricates

Nordstrom Valves

ROCKWELL MANUFACTURING CO.

400 N. Lexington Avenue • Pittsburgh 8, Penna.

Atlanta, Boston, Chicago, Columbus, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa.
Also leading supply houses
Export: Rockwell Manufacturing Co., International Division, 7701 Empire State Building, New York 1, N. Y.

KEEP [illegible]

. . . NOW REDESIGNED FOR STILL HIGHER EFFICIENCY

If you're pumping solids . . . not large enough to require regular non-clog slow speed sewage pumps . . . you'll find Economy volute mixed flow pumps the answer to your problem. Engineered for greater economy in operation, the Economy mixed flow volute line, tested and proved in twenty-two years of operation, has now been redesigned for still higher efficiency.

Built to keep pumping longer at lower cost these pumps are equipped with the highest duty bearings available, including double row, angular contact thrust bearing. Large size pumps also have a self-aligning, spherical roller radial bearing.

Capacities range from 3,000 to 50,000 G.P.M., heads from 10 to 50 ft. For complete details, write Dept. AC-10.

Centrifugal, axial and mixed flow pumps for all applications.

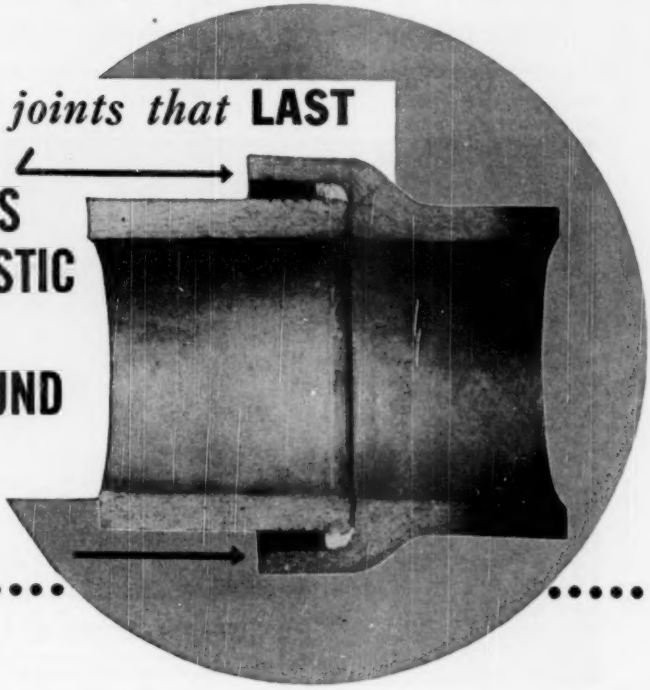
Economy Pumps Inc.

DIVISION OF HAMILTON-THOMAS CORP., HAMILTON, OHIO

Make joints that **LAST**

WITH

KOPPERS BITUMASTIC JOINT COMPOUND CPI-2



CLAY sewer pipe joints made with Koppers Bitumastic Joint Compound CPI-2 are strong and lasting as the pipe itself. That's because Bitumastic Joint Compound resists the three major enemies of sewer pipe joints — raw sewage, root penetration and line settlement.

Bitumastic has a base of specially-processed coal-tar pitch and is unaffected by sewage solutions and gases or by soil chemicals.

The tight seal Bitumastic Joint Compound CPI-2 makes between the bell and spigot prevents root penetration . . . both initially and after years of service because Bitumastic won't disintegrate with age or lose its bond.

In addition, Bitumastic Joint Compound CPI-2 has the right cold-flow characteristics to permit normal pipe movement caused by settling.

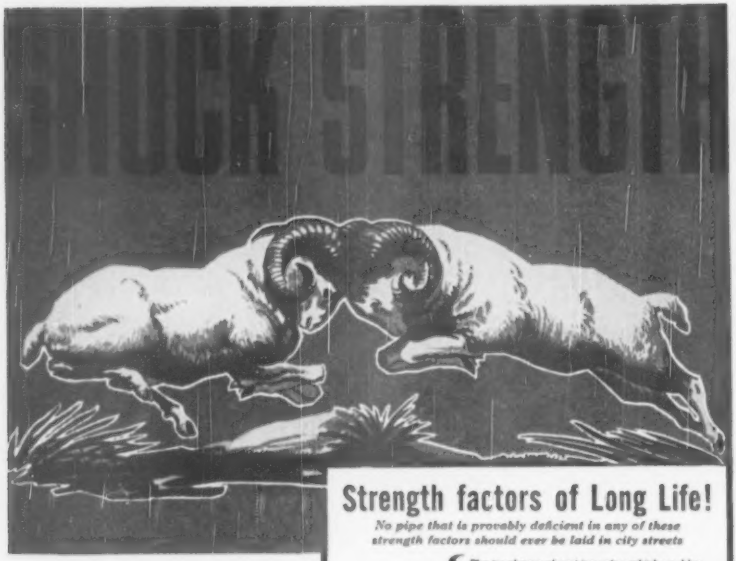
Specify Koppers Bitumastic Joint Compound CPI-2 for your next clay sewer pipe job. Use Koppers Bitumastic Enamels and Protective Coatings to protect your equipment against all forms of corrosion.

Here's the complete story

Our bulletin "Down to Stay!" tells you all about the advantages of Koppers Bitumastic Joint Compound CPI-2 . . . gives full details on applying it—on the ground or in the ditch. Write to Koppers Tar Products Division for your copy; there's no obligation.

KOPPERS **BITUMASTIC JOINT COMPOUND CPI-2**

KOPPERS COMPANY, INC., Tar Products Division, Dept. 1043T, Pittsburgh 19, Pa.



Without shock strength—or, for that matter—without all of the strength factors listed opposite—no pipe laid 100 years ago in *city streets* would be in service today. But, in spite of the evolution of traffic from horse-drawn vehicles to heavy trucks and buses—and today's vast complexity of subway and underground utility services—cast iron gas and water mains, laid over a century ago, are serving in the streets of more than 30 cities in the United States and Canada. Such service records prove that cast iron pipe combines all the strength factors of long life with ample margins of safety. No pipe that is provably deficient in any of these strength factors should ever be laid in city streets. Cast Iron Pipe Research Association, Thos. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3.

Strength factors of Long Life!

No pipe that is provably deficient in any of these strength factors should ever be laid in city streets

SHOCK STRENGTH — The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 8 times on the same spot from progressively increased heights of 6 inches.

CRUSHING STRENGTH — The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH — When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 19,800 lbs.

BURSTING STRENGTH — In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

CAST IRON PIPE SERVES FOR CENTURIES

SEWAGE AND INDUSTRIAL WASTES

The Journal of the Federation of Sewage Works Associations

Volume 22 | OCTOBER, 1950 | Number 10

Contents

Sewage Works

Literature Review on the Occurrence and Survival of Enteric, Pathogenic, and Relative Organisms in Soil, Water, Sewage, and Sludges, and on Vegetation. I. Bacterial and Virus Diseases. By Willem Rudolfs, Lloyd L. Falk, and R. A. Ragotzkie 1261

Keys to Successful Sewerage Services. By John M. Hepler 1282

Air Diffusion With Saran-Wrapped Tubes. By James H. Blodgett 1290

Study of the Nitrification Phase of the B.O.D. Test. II. Development of an Incubation Vessel for Multiple Determinations. By A. M. Buswell, Irene Van Meter, and J. R. Gerke 1297

Industrial Wastes

Application of pH Measurement and Control to Industrial Wastes. By W. N. Greer 1302

Waste Disposal at a Modern Brewery. By Ruben Schneider 1307

Treatment of Phenolic Plastics Wastes. By Norbert H. Kirchgessner 1314

Biological Oxidation of Formaldehyde. By Isaiah Gellman and H. Heukelekian 1321

Biological Treatment of Kraft Mill Wastes. By W. A. Moggio and H. W. Gehm .. 1326

Treatment of Plating Wastes at Electric Auto-Lite Plant, Lockland, Ohio. By Allen Reed 1338

Stream Pollution

Simplified Method for Analysis of B.O.D. Data. By Edward W. Moore, Harold A. Thomas, Jr., and William Brewster Snow 1343

Discussion by C. C. Ruchhoft 1353

The Operator's Corner

Safety in One-Man Operation 1356

Primary Devices and Meters for Waste Flow Measurements. By Howard O. Hite 1357

The Daily Log, Marion, Indiana. By David P. Backmeyer 1363

Sludge Utilization at Greenwich, Conn. By R. J. Kent 1368

Tips and Quips 1369

Proceedings of Member Associations

New England Sewage Works Association 1373

Central States Sewage Works Association 1373

Ohio Sewage and Industrial Wastes Treatment Conference 1374

Pennsylvania Sewage and Industrial Wastes Association 1376

Member Associations Meetings 1377

Reviews and Abstracts 1378

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois

Herbert P. Orland, *Assistant Editor* Dr. F. W. Mohlman, *Advisory Editor*

Kathleen E. Fox, *Editorial Assistant*

Copyright, 1950, by the Federation of Sewage Works Associations, Inc. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

Are your sludge disposal requirements...

Incineration

Drying for fertilizer

Drying or incineration

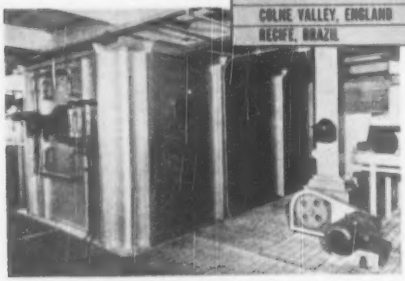
High temperature deodorization

?

THE C-E RAYMOND SYSTEM is the *only* proven method of sewage sludge disposal that can meet any combination of these requirements. It is flexible and efficient... provides for maximum utilization of waste heat.

The table (right) illustrates the adaptability of the C-E Raymond System to the specific requirements of any community.

CITY	INCINERATION	DRYING	DRYING OR INCINERATION	HIGH-TEMPERATURE DEODORIZING
CHICAGO, ILLINOIS				
CALUMET			✓	✓
SOUTHWEST			✓	✓
WEST SOUTHWEST			✓	✓
BUFFALO, NEW YORK	✓			✓
TENAFLY, NEW JERSEY		✓		✓
SPRINGFIELD, MASS.			✓	
NEENAH-MENASHA, WIS.	✓			✓
WATERVLIET, NEW YORK	✓			✓
CUYAHOGA FALLS, OHIO	✓			
DULUTH, MINNESOTA			✓	✓
MANITOWOC, WISCONSIN		✓		
SAN DIEGO, CALIFORNIA		✓		✓
STAMFORD, CONNECTICUT			✓	✓
SHEBOYGAN, WISCONSIN		✓		✓
BATTLE CREEK, MICHIGAN		✓		
SAN DIEGO, CALIF. EXTEN.		✓		✓
HOUSTON, TEXAS		✓		
LOS ANGELES, CALIFORNIA			✓	✓
FOND DU LAC, WISCONSIN		✓		✓
SAN FRANCISCO, CALIF.		✓		✓
BALTIMORE, MARYLAND		✓		
WATERBURY, CONNECTICUT			✓	✓
COLNE VALLEY, ENGLAND			✓	✓
RECIFE, BRAZIL		✓		



C-E Raymond System at Duluth, Minn. Photo taken from operating floor showing part of furnace.

All inquiries on the C-E Raymond System should be directed to the nearest office of The Dorr Company, world sales representatives in the Sanitary Engineering Field.

In sewage treatment...there's a Dorr Unit for practically every step in every flowsheet.

DORRCO

THE DORR COMPANY, ENGINEERS
BARRY PLACE, STAMFORD, CONN.
NEW YORK • ATLANTA • TORONTO
CHICAGO • DENVER • LOS ANGELES
RESEARCH AND TESTING LABORATORIES
WESTPORT, CONN.
SUGAR PROCESSING
PETREE & DORR DIVISION, STAMFORD, CONN.
ASSOCIATES AND REPRESENTATIVES
Dorr Technical Services and Equipment Are Also Available Through Associated Companies and Representatives in the Principal Cities of the World. Names and Addresses on Request.

DORR

RESEARCH ENGINEERING EQUIPMENT

Sewage Works

LITERATURE REVIEW ON THE OCCURRENCE AND SURVIVAL OF ENTERIC, PATHOGENIC, AND RELATIVE ORGANISMS IN SOIL, WATER, SEWAGE, AND SLUDGES, AND ON VEGETATION *

I. Bacterial and Virus Diseases

By Willem Rudolfs, Lloyd L. Falk, and R. A. Ragotzkie

General Introduction

The use of human excreta for fertilizer, ranging from night soil application to irrigation with sewage or polluted river water, is a world-wide practice. Although "advanced" hygienic western civilizations deplore these night soil practices of the majority of the world's people, the economy of such highly populated countries as China and India would be wrecked without human manure. As a matter of fact, the wastage of organic and inorganic fertilizer by modern municipal sanitary practices, which send sewage and sludge to sea, has been the subject of many published attacks.

Aside from aesthetic reasons the principal objection to soil fertilization with human waste products has been the potentialities of the transmission of human disease and parasitic infections through consumption of raw vegetables grown on such soil. Attempts to conserve various sewage sludges for fertilizer depend to a considerable extent on the health aspects of their use.

A detailed survey of the available literature was made and the information brought together to form a broad background for the understanding of the problems involved in the sanitary aspects of the consumption of raw fruits and vegetables.

The survey has been divided into two general parts: (1) a review of the viability of the more common intestinal pathogenic organisms of a bacterial or virus nature, which could cause disease by ingestion of contaminated raw fruits and vegetables (typhoid, paratyphoid, bacillary dysentery, cholera, tuberculosis, streptococcal infections; also coli-aerogenes group, as well as poliomyelitis virus); and (2) microorganisms of animal nature, including the causative agents of amebiasis and amebic dysentery, hookworm, tapeworm, and ascariasis. Although the review does not include all intestinal human pathogenic or parasitic microorganisms, it is believed that the organisms considered represent the most common diseases that might be transmitted through eating raw vegetation grown under diverse sanitary and farming conditions in most parts of the world.

Usually a literature survey leaves the reader with a mass of material difficult to assimilate. In an effort to facilitate the use of the present survey and aid the reader, the main points or

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

conclusions drawn from the survey pertaining to each group or sub-group of organisms are given. In addition, a brief general summary of findings dealing with bacterial and virus diseases is included.

Salmonella Types

Salmonella *Types in Soil*

Not long after the discovery of the organism that causes typhoid fever, attempts were made to determine its longevity in soil. Granger and Deschamps (30) claimed to have recovered *Eberthella typhosa* from soil after 5½ months. Karlinski (45) reported a survival of 3 months in natural soil. Demster (21), after inoculating sterile soil with the organism, recovered it after 18 days. In a sterile peat, the bacillus disappeared in 24 hr. The greater death rate in peat may have been due to a higher hydrogen-ion concentration characteristic of certain peats. He considered that if the soil itself does not have a destructive action on the bacillus, then the viability is chiefly dependent on the soil moisture.

Martin (58), inoculating sterile virgin soils with *E. typhosa*, found they died out rapidly, but in sterilized contaminated soils growth occurred and the bacteria were found alive even after 400 days. As the bacteria were added to the soil as a broth culture, it may have been the nutrients of the media which sustained the bacteria, not the soil itself. Robertson (75) also found that when the *E. typhosa* was added as a broth culture to natural soil, the survival was 10 months when frequent additions of nutrient material were made and only 4 months without such frequent additions. Rullman (80) found the organisms 216 days after adding a broth culture to sterilized soil and 100 days after addition to an unsterilized portion of soil.

Firth and Horrocks (25) found that typhoid organisms do not multiply or move about in soil, but can be washed by water even from closely packed soil. It also was found that some of the organisms can exist up to 74 days in ordinary or polluted soil, depending on the soil moisture. The survival time is reduced to 25 days in dry sand. In the surface soil layer the organisms were viable after 122-hr. exposure to sunlight distributed over a period of 22 days. Sedgwick and Winslow (87) also found that survival in moist soil was longer than in dry soil. In the latter, 99 per cent of the organisms were destroyed in two weeks.

Levy and Kayser (53) reported the longevity of typhoid organisms in feces of a privy vault as over 5 months, including a 2-week period when the feces were used as manure on a garden.

Smith (91) did not believe that soil, because it had at one time been inoculated with typhoid organisms, should be regarded as a continuing source of infection. He concluded that the organism can exist for but short periods in natural soils or after inoculation into sterilized soils.

Galvagne and Calderini (29) found the longevity of *E. typhosa* to be about 30 days in a privy vault. If, after 10 days, the feces were spread upon the ground surface or buried in deeper layers, the viability was 20 additional days on the surface and 40 additional days buried.

Melick (60) showed that *E. typhosa* survived from 29 to 58 days, depending on the soil. Survival was extended to 74 days in sandy soil (hothouse conditions) by the addition of sterile sewage. Murillo (65) found similar results in Spain, the organism being viable after 30 to 36 days in garden soil and 55 days in sterile sand.

Kligler (47) found that *E. typhosa* and *B. dysenteriae* remained alive in feces up to 10 and 8 days, respectively. A somewhat longer survival was found in solid than in liquid stools. In septic tanks, the typhoid organism could be isolated after 8 to 15 days. The survival was better in "unripe" tanks with low alkalinity.

He found that moist, slightly alkaline soils were most favorable for the survival of *E. typhosa*. In moist soil the survival was up to 80 days, but only 20 in dry soil and 10 in acid soils. It was also noticed that *B. proteus* and *P. fluorescens*, organisms frequently found in soil, have an antagonistic effect on *E. typhosa*, as well as on *B. dysenteriae*.

Beard, Carlson, and Chambers (8) and Beard (6)(7) found that the water-holding capacity of a soil, the temperature, rainfall, sunlight, organic material in the soil, and the hydrogen-ion concentration all have an influence on the longevity of the typhoid bacillus. The following tabulation shows the results obtained (7) for the days of survival and per cent death during the first 24 hr. of *E. typhosa* in various soils during a wet and dry season.

Soil	% Death, 1st 24 hr.		Days known survival	
	Wet	Dry	Wet	Dry
Adobe	25	45	42	21
Adobe peat	30	50	42	28
Loam	28	45	49	21
Sand	70	95	8	4
Peat	99.99	—	1	2

Survival was almost tripled during a long rainy season. The rapid death rate in peat was attributed to a lethal pH value. The pH effect did not seem important within the range of ordinary soils. This is in agreement with the results of Demster (21) as previously mentioned. The death rate was also higher by about 36 per cent in the first 24 hr. in soils exposed to sunlight. Survival was also longer in natural soil (85 days) than in soils polluted with sewage (45 days) or feces (27 days).

Contrary to Kligler, however, Beard found that *Proteus vulgaris* and *Pseudomonas fluorescens* had no antagonistic effect on *E. typhosa*.

Beard also found that the typhoid bacillus survived for two years in moist soils and one year in feces at freezing temperature.

Pasricha and Paul (70) found, in soils of India as far down as 3 ft. below the surface, phages which were active, in order of decreasing frequency, against bacillary dysentery, typhoid, and cholera.

Loots (55) pointed out that the South African Department of Agriculture and Forestry suggested that disease would not be spread by night soil that had been composted for two to three weeks at temperatures of 100° to 160° F.

From the results presented, certain general conclusions suggested themselves concerning the fate of *E. typhosa* in soil.

1. The viability was variable, having been reported ranging from less than 24 hr. in peat to more than two years in freezing moist soils, but generally less than 100 days.

2. The moisture content of the soil appeared important, the trend being for greater survival in the moister soils.

3. The moisture holding capacity was of influence—that is, survival was less in sandy soils than in soils of higher water-holding capacity.

4. Colder temperatures increased the survival of *E. typhosa*.

5. Longer survival time in soil, as compared with feces, had not been definitely demonstrated.

6. The low pH values of peat and acid soils were unfavorable to *E. typhosa*.

7. Sunlight was unfavorable to *E. typhosa* in soils, but this may have been more of a heating and drying effect, than of lethal effects of sunlight.

8. The antagonistic or beneficial effects of other microorganisms in soil on *E. typhosa* had not been conclusively demonstrated. Greater survival of the organism after inoculation into sterilized than into unsterilized soil indicates antagonistic effects. However,

whether this was due to effects of other bacteria or to the predatory action of higher forms of life, such as protozoa, had not been established.

9. The presence of pollution in soil in the form of sewage or feces either had no effect or reduced the survival of the typhoid bacteria. Whether this was due to the presence of added organic matter or to the antagonistic effect of sewage organisms was not demonstrated.

Salmonella *Types on Vegetation*

The possibility of the spread of typhoid fever and other intestinal diseases through eating contaminated vegetation has concerned many investigators for several years.

Kozyn (48), investigating field-grown vegetables near Moscow, commonly found intestinal bacteria on the plants, but could not show the presence of typhoid bacteria. It was also noted that the bacteria could not penetrate the unbroken surface of the plant. Remlingen and Nouri (73) also found no pathogenic organisms entering the plants. Those on the surface of plants from sewage irrigation farms were only *B. anthracis* and *B. tetanus*, the former rare in sewage, the latter harmless on ingestion.

Lumsden and Anderson (56) felt, on the other hand, that typhoid fever in Washington, D. C., was possibly caused by the use of green vegetables grown on polluted soil. Creel (20) showed that *E. typhosa* could be recovered from the leaftips of plants grown on infected soil. Rain did not completely wash off the infected material. The organisms were able to survive at least 31 days, a period sufficient for the growth and use of such raw vegetable crops as lettuce and radishes.

Melick (60) noted that typhoid organisms could infect vegetables grown on infected soil. Radishes grown in soil fertilized with typhoid stools were found infected with typhoid bacteria in three experiments after 28 to 37 days and on lettuce after 21 days. However, it must be noted that he found positive returns on the vegetables only when the typhoid-stool fertilizer was bolstered by agar-grown organisms from these feces.

The increase of typhoid in Paris in summer had been thought partially due to the consumption of raw vegetables grown on a Paris sewage farm (2). Thorough washing of vegetables to which typhoid bacilli had been applied failed to completely remove the organisms.

The observation of outbreaks of *Salmonella pullorum* in hospital patients who had no contact with poultry led Felsenfield and Young (24) to investigate the survival of *Salmonellae* on raw vegetables, as they may become a source of infection if they have become contaminated with chicken droppings. They studied the following species of *Salmonella: pullorum, typhimurium, montevideo,* and *oranienburg*. The vegetables studied were green beans, beets, cabbage, carrots, celery, cucumber, lettuce, onions, green peppers, green peas, radishes, spinach, tomatoes, and turnips.

They found that *S. pullorum* survived 4 to 8 weeks on vegetables in the icebox (2° to 4° C.) and 2 to 5 weeks at room temperature. On onions the survival was short because of the antibacterial action of this vegetable, known for some time. The other strains survived about two weeks longer than *pullorum*. The authors concluded that, because of the long survival period, it would be possible for infections to occur from consumption of contaminated vegetables. It must be pointed out, however, that it is not field survival that is being dealt with, but survival under fairly constant laboratory conditions.

Mills, Bartlett, and Kessel (61) confirmed results of previous investigators that bacteria did not penetrate the unbroken skin of fruits and vegetables,

but could remain on the surface 15 days or longer under moist conditions. Further, they found that normal uninjured fruits and vegetables contained no living microorganisms in their tissue, but bacteria pathogenic to man were able to enter injured or decayed parts and remain alive for 7 to 42 days. Dipping the vegetables in chlorinated water or for 10 seconds into boiling water was found effective in freeing the vegetation from pathogenic bacteria, but not from cysts and eggs of higher animal parasites.

Suzuki (96) found that solutions having less than 3 p.p.m. of chlorine killed the germs of typhoid in less than 15 min., of dysentery in 30 min., and of cholera in less than 5 min. On vegetables, however, not all typhoid bacteria were killed in 40 min. with 200 p.p.m. of chlorine. This was believed due to the inability of the chlorine to reach the deeper parts of the leaves and stems. When curled leaves and stems were removed, 20 p.p.m. was effective in from 5 to 15 min. It was also possible that the lower killing power of chlorine in the presence of vegetables was due to reducing action of the organic material. Suzuki considered that mass disinfection of vegetation in the food markets of Japan would be ineffective.

In Colorado, where water conservation and irrigation are practiced, Chapman (16) pointed out a typhoid rate considerably higher than the national average. He attributed this to the absence of laws preventing the sale of foods to be eaten raw which had been grown under irrigation with contaminated water. In California, he pointed out, such irrigation practices exist, but laws prevent use of such irrigated vegetation, thus resulting in a lower typhoid rate.

In 152 samples of Berlin sewage, Papenberg (67) found paratyphoid B bacteria twice and those of paratyphoid A only once. In comparison with the number of coli, proteus, and fluorescens types, this was very small. However, the paratyphoid organisms were found in the ditches leading to irrigation fields of sewage farms and from a sewage settling tank, indicating a possibility of raw vegetables being a source of paratyphoid infection.

McCloskey and Christopher (59) investigated the viability of certain pathogenic bacteria in strawberries frozen and stored at − 18° C. On sliced sweetened berries so stored, survival of *E. typhosa* was 6 months, *Salmonella aertrycke* and *S. schottmuelleri*, 1 month, whereas *S. paratyphi* was not recovered after freezing. On the uncut sweetened berries, *E. typhosa* survived for 14 mo. If *E. typhosa* was inoculated into sliced sweetened berries incubated at 4° to 5° C., the rate of death was 98 per cent the first day and 100 per cent in 8 days. At 22° to 27° C., the organism could not be recovered after 6 hr.

The literature presented on the fate of typhoid and paratyphoid organisms on vegetation has, in general, shown the following:

1. Human pathogenic bacteria cannot penetrate the unbroken skin of undamaged fruits and vegetables. However, they may be found in damaged portions, where they are viable for considerable periods.

2. Crops grown on infected soil containing typhoid organisms will have these organisms present on their leaf and other surfaces. The viability of these organisms has been noted to range from 20 to 40 days, a period sufficient for some crops normally eaten raw to mature and be consumed.

3. Simple rinsing of raw vegetables, and even dipping in certain antiseptic solutions, is not sufficient to remove the pathogenic organism from the surfaces. Immersion in boiling water for a short period appears more effective.

4. Indirect evidence from various parts of the world would indicate that raw fruits and vegetables grown in

contaminated soil or irrigated with sewage or sewage-contaminated water may be a source of increased or above-normal typhoid incidence.

5. Typhoid organisms may survive very cold storage on foods for some time.

6. Laboratory tests on the survival of *Salmonella* on vegetable surfaces indicate these organisms can survive 7 to 10 weeks at room temperature and icebox temperature. Thus, contamination deposited during harvest or handling by infected carriers may be carried to the consumer.

Salmonella *Types in Water*

The literature on the survival of pathogenic and parasitic organisms in water with varying degrees of pollution, as well as in sewage and sewage sludges, is of interest because of the close relation to polluted soil, feces, and night soil.

Jordan, Russell, and Zeit (44) were among the first to study the viability of the typhoid bacillus in water. They found that the survival time of the organism was an inverse relation to the degree of contamination. For example, in sterile tap water the organisms survived for 15 to 25 days, but only 4 to 7 days in unsterilized tap water. In raw river water the period of survival was only 1 to 4 days; in raw drainage canal water the survival was only 2 days.

On the other hand, Wheeler (101) found opposite results. The maximum survival time was given in various types of water according to the following table:

Temperature (° C.)	Maximum Survival Time (days)		
	Distilled	Tap	Polluted Well
10–12 (dark)	17	21	37
37 (dark)	15	17	17
20 (dark)	37	43	79
20 (light)	13	15	15

Here, the greater the pollution, or presence of dissolved material, the longer the survival. In the dark, temperatures about 20° C. were more favorable than 10° to 12° or 37° C. The absence of light apparently was also beneficial to the viability of the typhoid organism.

Whipple and Mayer (102) studied the effect of the presence of oxygen and of its absence on the longevity of the typhoid bacillus in sterile tap water. At 20° C., under an atmosphere of oxygen, the longevity was 50 days; under an atmosphere of hydrogen, only 4 to 8 days.

Hinds (38) found that the death rate of the typhoid organisms was higher under nitrogen and hydrogen than under an atmosphere of oxygen. The death rate also increased with increasing temperature (8° to 20° C.).

Fehrs (23) found that *E. typhosa* would live 7 days in unsterilized tap water, 46 days after inoculation into that same water after sterilization, and only 13 days in the same sterile water when flagellated protozoa were also introduced.

Russell and Fuller (81), following up work by Jordan, Russell and Zeit (44), found that *E. typhosa* survived in pure surface water for 8 to 10 days, and only 3 to 5 days in sewage. When raw surface water was seeded with typhoid bacteria and kept in collodion-like sacs immersed in flowing sewage, survival was 10 to 14 days. His results would indicate that direct contact with sewage organisms was more detrimental to the vitality of the typhoid organism than contact with the diffusible by-products of sewage organisms or those soluble compounds normally found in sewage. Other factors, not mentioned, may have been influential, such as changes of pH on the storage of the sewage and the predatory factors of protozoa in sewage.

In stream purification studies, Ruediger (79) found that typhoid and colon bacilli disappeared about 5 or 6

times more rapidly from polluted river water in summer than in winter when the river was covered with ice and snow. He considered the sun's rays of importance, but even more so was the increase in summer of microscopic plants, protozoa, and saprophytic bacteria.

In the same year, Frankland (28) showed that typhoid organisms survived longer in sterilized polluted surface waters (20 to 51 days) than in unsterilized surface waters (9 to 13 days).

Houston (41) found that the previous history of the typhoid organism influenced its viability in river water. Freshly isolated organisms were viable for 1 to 3 weeks, whereas those which had been cultured for some time were viable for 1 to 8 weeks. He also found that the viability in river water of cultured organisms decreased with lower temperature as follows:

Temperature (° C.)	Viability (weeks)
0	9
5	7
10	5
18	4
27	3
37	2

The greatest reduction, however, was during the first week in all cases.

Flu (27) found that the viability of typhoid organisms in large reservoirs exposed to the sun (Dutch East Indies) was 7 to 8 days.

Cohen (17) studied the tolerance of *E. typhosa* and *Escherichia coli* to hydrogen-ion concentrations. The former exhibited greatest tolerance within the zone pH 5.0 to 6.4. An increase of acidity beyond this zone resulted in rapid mortality. For *Esch. coli* the zone was wider and centered about neutrality. He also investigated the effect of disinfectants and found that for both organisms the mortality followed logarithmic declines. The relative resistance of *Esch. coli* to *E. typhosa* decreased with temperature rises from 0° to 10° to 20° to 30° C. in the ratio of 67 to 51 to 18 to 8.

Scott and McClure (86), who investigated higher pH values, found that the colon-typhoid group of bacteria were destroyed in media of high pH, the limiting value being about 9.5.

Arnold (4) investigated the presence of phages in Chicago River waters. The phages concentration is in direct proportion to the concentration of domestic sewage. He concluded that such phages-sensitive organisms as those of typhoid and dysentery would be less liable to cause epidemics in water containing the phage than the same number of bacteria in phage-free waters.

Wibaut and Moens (103) found that *E. typhosa* disappeared from tap, rain, and swimming pool water in 7 to 10 days and corresponded with increases of certain bacteria-eating protozoa. However, in ground water the survival was four weeks, in presence of the same protozoa, and a few days longer in absence of the protozoa.

Ballantyne (5), who compared the survival of *E. typhosa*, *Esch. coli*, *M. tuberculosis*, and *Strep. hemolyticus* in distilled water and in 0.85 per cent sodium chloride solution, found survival longer in the first. *E. typhosa* survived 5 times as long at room temperature as at 37° C. He concluded that low temperature, a minimum of nutrients and a minimum or absence of sodium chloride, and a high bacterial concentration favor bacterial survival, but not growth.

Kyriasides (51) found that typhoid and cholera organisms disappeared in 4 to 6 days after inoculation into unsterilized tap and River Spree water and after 13 to 16 days in well water. After sterilization survival was longer, but was significantly reduced to about 2 days when protozoa were also added to the sterilized tap and river waters.

Beard and Meadowcroft (9) indicated the possibility that *E. typhosa*

and *Esch. coli* survived for at least a month in sea water.

Hoskins (40) reported on the bacterial purification rates of polluted water in experimental channels. His experiments indicated that the total bacterial count decreased in rivers due to bacteria-eating plankton.

Rubentschik, Roison, and Bieljansky (77) found that the ground sediments of salt lakes adsorbed bacteria, which may survive 40 to 80 days in this adsorbent mud.

Ruys (82) showed that typhoid bacteria were killed in canal water at 24° C. in 6 days, but were still viable after 6 days in tap water at the same temperature.

Beard (6) found that *E. typhosa* tended to survive longer in clean water and that the survival in salt water (32 days) was similar to that in fresh water. Ice was found favorable for preservation of *E. typhosa*.

Recent work has been published by Wattie and Chambers (100), Butterfield, Wattie, Megregian, and Chambers (13), Wattie and Butterfield (99), and Butterfield and Wattie (12) on the effects of excess lime treatment of water and free chlorine and chloramine on coliform and enteric pathogens. Treating water with excess lime, they found that complete kill of pathogens was not obtained after 6-hr. contact below pH 10.5. Of the pathogens studied, including *Esch. coli*, *A. aerogenes*, and *Shigella* strains, *E. typhosa* was the most resistant. However, complete kill of pathogens was obtained at room temperature at a pH of 11.0 to 11.5 in 2 hr. and at pH 10.5 to 11.0 in 4 hr. A higher death rate was obtained with pathogens than with nonpathogens; the death rate also was lowered with lowered temperature.

Observations were made on the survival of *Esch. coli*, *Ps. pyocyanea*, *E. typhosa*, and strains of *Shigella dysenteriae* when exposed to free chlorine. The time of exposure and concentrations were the primary factors influencing the extent of kill with free chlorine. Higher hydrogen-ion concentrations (studied pH 7.0, 8.5, 9.8, and 10.7) and higher temperatures (20° to 25° C. compared with 2° to 5° C.) increased the bactericidal efficiency of free chlorine.

E. typhosa was found more resistant than *Esch. coli* at pH 6.5 and 7.0, but the latter was more resistant above 8.5. At pH 7.8 the coli strains were more resistant when free chlorine was in excess of 0.03 p.p.m. Wattie and Butterfield (99) considered this "changeover" in sensitivity to be due to differences in the permeability of the capsular material of each organism to free chlorine at the different pH values studied. Only slight differences in the sensitivity of those two organisms toward chloramine were noted.

The difference in the bactericidal action of free chlorine and chloramine was also studied. For *Esch. coli*, to obtain 100 per cent kill at normal pH in the same time, about 40 times as much chloramine was required. For *E. typhosa*, this ratio was about 25 to 1.

The action of chloramine was similar to that of chlorine in that the efficiency of chloramine depended on the concentration and exposure time. Its efficiency decreased with lower hydrogen-ion concentration and temperature. A reduction of temperature (from 20° to 25° to 2° to 6° C.) required 9 times the exposure period and 2.5 times as much chloramine to produce 100 per cent kill. Chloramines, however, were less efficient bactericidal agents than free chlorine.

Salmonella *Types in Sewage and Sludges*

Closely related to the survival of typhoid organisms in water is their viability in sewage. Also the use, for fertilizing, of certain organic sludges from various sewage treatment methods has stimulated interest in the possibility of transmission of disease by such sludge uses.

The behavior of typhoid organisms inoculated into septic tanks in Batavia by Flu (26) was such that the organism was not recovered after 4 to 7 days. Courmont *et al.* (18) invariably found members of the typhoid-paratyphoid group present in activated sludge effluents after 6-hr. aeration.

Wolman (109) found that *E. typhosa* could survive anaerobic sludge digestion up to 7 days.

Gray (31) reported 7 isolations of the paratyphoid organisms from 20 samples of Edinburgh sewage. All isolations were from a district which had suffered an outbreak of the disease two years previously. More than a year later, Begbie and Gibson (10) reported 7 isolations of the organisms from 58 samples of Edinburgh sewage.

Rochaix (76) noted that the organisms of typhoid, paratyphoid, and cholera increased their survival from a range of a few hours to 11 days in unsterilized domestic sewage to as much as 20 months after inoculation into sterile sewage. Wilson and Blair (106) concluded that the typhoid bacillus could survive more than 5 weeks in sewage at room temperature in the light (British Isles). On the other hand, Stewart and Chosal (94) found them to have disappeared from sewage and feces within one week (India).

Bruns and Sierp (11), using a sewage containing 450,000 typhoid organisms per milliliter, found the organisms reduced 96 per cent after 12-hr. treatment with activated sludge. The greatest effect was obtained in the first 6 hr., most of the organisms having been transferred from the liquid to the sludge phase. Similar reductions were found with paratyphoid, bacillary dysentery, and cholera organisms. Anthrax spores were found to be more resistant. It was suggested that the plankton present in the sludge were important in the reduction of the pathogenic organisms.

Pesch and Sauerborn (71) reported a 50 per cent reduction of paratyphoid B organisms after 1 hr. in activated sludge; no further reduction was noted until the second day. Bruns and Sierp (11) noted that the pathogenic organism was still found in considerable numbers in the sludge even after prolonged aeration. Stewart and Chosal (93), however, found a 99 per cent reduction of the typhoid and paratyphoid bacilli after 6-hr. treatment of sewage with activated sludge. Edwards (22) reduced by 96 to 98 per cent the typhoid, paratyphoid, and cholera bacteria inoculated into sewage treated with 15 per cent activated sludge and aerated for 14 hr. About 50 per cent of anthrax spores were recovered after 6-hr. aeration.

Ruchhoft (78) found 14 per cent of *E. typhosa* survived 5.5-hr. aeration in activated sludge. The survival of the organism in the stored sludge was about 80 days at 50° to 60° C. and 13 to 14 days at 68° to 72° F. The ratio of *E. typhosa* to members of the coli-aerogenes group was found to be 1 to 7,700 in the activated sludge of the Chicago North Side treatment works. On the basis of his results, Ruchhoft recommended that caution be observed when using wet activated sludge as a fertilizer in truck gardens. No recommendations on the use of the dry sludge were made.

Hajna (33) found 6 samples positive for *E. typhosa* out of 22 samples tested from 5 plants. In the raw sludge, 3 out of 7 samples from 2 plants showed positive results. Plant effluents and digester effluents showed no positive results out of the 9 and 3 samples, respectively.

Heukelekian and Schulhoff (36) studied the survival of *E. typhosa* in surface waters and sewage. They concluded that the death rate in polluted water and sewage was rapid, being 99 per cent in 6 to 10 days. The rate of decrease was greater at 22° C. and 37° C. than at 2° C. In polluted river water and in sewage, the survival was 12 and 17 days, respectively, at 2° C., 2

and 3 days at 22° C., and 1 day in both at 37° C. Under favorable temperature conditions and in the presence of an available food supply, *E. typhosa* could multiply; but survival was not prolonged, as the subsequent decline was proportionately greater. When small amounts of such organic material as feces, urine, sewage, and broth, or material carried over from broth cultures, were added to unpolluted water, they constituted a food supply resulting in actual multiplication when *E. typhosa* was introduced, the extent of multiplication depending on the amount of food present.

In polluted waters survival was shorter than in non-polluted waters. Competition for food by other bacteria and attack by protozoa were considered probable causes of this shorter survival.

Under starvation conditions *E. typhosa* and *Esch. coli* did not affect each other. However, the survival of *E. typhosa* was reduced in the presence of food material upon addition of *Esch. coli*.

The destruction of *E. typhosa* in partially chlorinated sewage was similar to that of the normal sewage flora. Only 25 per cent of the chlorine demand had to be satisfied to obtain a 99 per cent kill of *E. typhosa* after 10-min. contact.

Shimomura (89), in studies in Formosa, found the survival of *E. typhosa* in sewage was longer in winter (26 days) than in summer (7 days). It was also noted that *Esch. coli* survived longer than the typhoid organism.

Tanner (97) reviewed the public health aspects of utilizing sewage sludge as fertilizer. Sludge should be applied with caution on soil to be used for growing vegetables to be eaten raw. He considered late fall, winter, or early spring the best time for adding the sludge to the soil.

Green and Beard (32), studying the survival of *E. typhosa* in certain sewage treatment processes, found that the organism survived at least 19 days in stored raw sewage at room temperature, the time increasing to at least 27 days when stored outdoors at a lower temperature. In activated sludge, reduction in the liquid was 91 to 99 per cent after 6-hr. aeration and 99.9 per cent in 24 hr. If the activated sludge was partially sterilized at 80° to 95° C. for 20 min. (to kill protozoa and nonsporeforming bacteria), the typhoid organisms increased for the first 3 days and then very rapidly decreased so that after 4 days there was little difference from the untreated control, which had shown a 1 per cent survival of *E. typhosa* after the first 6 hr. of aeration. Thus, it was concluded that biological activity, and not aeration, was responsible for the reduction.

Mom and Schaeffer (62) and Schaeffer (84)(85) investigated the occurrence of the typhoid organism in sewage of two Netherland East Indies communities. They concluded that the typhoid bacteria present were from human feces and urine. An 80 per cent reduction was noted in an Imhoff tank, which was attributed to the partial removal of the bacteria from the liquid phase by the settling of coarser and the flocculating of finer particles. The pathogen was found in the sludge after 1-month digestion, but not in sludge dried on sand beds.

Stokes, Jones, and Miles (95) found that paratyphoid B bacteria could be isolated intermittently for 41 days from 0.1 g. of drying sludge containing an initial inoculation of 25,000,000 organisms per milliliter of sludge. *E. typhosa* could be recovered after 180 days, when the moisture had reached 14 per cent. The initial concentration was 7,500,000 per milliliter of sludge. The organisms could also be isolated throughout a 45-day anaerobic digestion period, the decrease in the yield of typhoid organisms paralleling that of the total flora.

In 33 samples of partially dried sludge from various sewage treatment

plants, no typhoid organisms were isolated, even though the disease had occurred in some districts during recent previous years.

These authors further reported:

"So far as is known there is no record either in this country (England) or in America of an outbreak of serious intestinal infection which could be attributed definitely to the handling of sewage sludge or from the consumption of crops grown on land fertilized by sludge. Although the present work has shown that pathogenic bacteria initially present in extremely large numbers do survive both drying and digestion, the risk of such bacteria surviving in sludge from sewage containing comparatively small numbers of the bacteria would be small. Nevertheless it is a sound precaution to avoid using sewage sludge on salad and other crops which are eaten raw."

Wilson (105) pointed out that "since in well nigh 100 years of practice in Europe no outbreak of disease has been definitely traced to the use of sewage sludge as fertilizer, the risks cannot be great."

Summary of Literature on Salmonella *Types*

In summary, the literature on the viability of *Eberthella typhosa* in soil, water, sewage, sewage sludges, and feces, and on vegetation brings out the following:

1. The survival of the organism has been reported by numerous investigators with considerable variation as to results. Among the factors influencing the survival are:

   a. Method of isolating, identifying, and enumerating *E. typhosa.*
   b. Initial number of *E. typhosa* present.
   c. Temperature.
   d. Hydrogen-ion concentration as well as the concentration of inorganic salts.
   e. Moisture content of soil and sludges.
   f. The presence of organic material in the substrate and its usefulness to *E. typhosa.*
   g. The antagonistic predatory and beneficial effects of other microorganisms.

2. The initial number of *E. typhosa* present appeared to have influenced the time required to free a particular substrate from the organism. Although some data on the death rate of typhoid in sewage and water are available, the natural death rate of *E. typhosa* in soil, night soil, and feces under varying natural conditions has not been extensively studied.

3. As a general rule, it seems that the survival of *E. typhosa* (and also of several other pathogenic and nonpathogenic bacteria) is lengthened by lowering the temperature. This has been shown to hold in soil, water, sewage, and sludge and for the bactericidal activity of certain disinfectants.

4. The viability of *E. typhosa* is affected by the hydrogen-ion concentration of the substrate. The optimum pH value apparently lies somewhere between 6 and 8, although 5 to 10 may be tolerated for a time if other conditions are favorable. Beyond these values, the organism is definitely in an unfavorable environment and is usually killed in a few hours. The effect of various concentrations of inorganic salts is obscure. Lower salt concentrations appear unfavorable, but, on the other hand, *E. typhosa* has been shown to be viable in sea water for at least a month under certain conditions.

5. One of the most important factors affecting the survival of the organism in soil and sludges is the moisture content. Increased moisture is apparently favorable for the survival of *E. typhosa.*

6. The presence of other organic matter must, of course, be reflected in its effect on *E. typhosa*. In earlier work, when the organism was added to soil as a broth culture, the presence of such nutrients must have influenced the survival of the bacillus. One must also consider whether the organic matter can be utilized as an energy source for the bacterium as well as the effect of other microorganisms on the organic matter. Heukelekian and Schulhoff (36), as pointed out before, showed that small amounts of feces, urine, sewage, and culture broth in unpolluted water may permit *E. typhosa* to increase.

7. The presence of organic matter may, on the other hand, favor the growth of microorganisms having an antagonistic effect on *E. typhosa*. Many investigators have found that typhoid organisms survive for considerably longer periods after inoculation into sterile soil, water, sewage, sludge, and feces than into the same substrate unsterilized. It has also been shown that the presence of protozoa in water and sewage increases the death rate of *E. typhosa*; the rapidity with which activated sludge removes the organism of sewage is similarly indicative. The antagonistic effect of other bacteria has not been thoroughly investigated.

Coli-Aerogenes Group

Although *Escherichia coli* is not an organism pathogenic in nature, its universal presence in intestinal tracts and its comparative ease of identification have long made it useful as an indicator of fecal pollution in water. Thus, the possibility of using this organism as an indicator of pollution of raw vegetation cannot be overlooked.

The universality of *Esch. coli*, as well as its survival outside the animal body, is illustrated by the work of Young and Greenfield (112). Twenty-five samples of soil from the state of Kansas were examined for colon organisms. All were apparently free from recent animal and human pollution, yet all but one showed the presence of the coliform group. In another experiment, soil containing *Esch. coli* was kept on top of a tall building, protected from birds; coli were present in 0.01 g. of soil after 5 years. Laboratory experiments carried out by these investigators showed that the optimum soil moisture for *Esch. coli* was between 10 and 40 per cent of saturation.

Skinner and Murray (90) found that in soil containing 0.5 per cent feces by weight and with an initial content of 600,000 *Esch. coli* per g., the coli survived 122 to 136 days. *Aer. aerogenes* of fecal origin was found to survive somewhat longer. Pure cultures of *Esch. coli* and *Aer. aerogenes* disappeared in 176 to 197 and in 218 to 248 days, respectively, from soil. (In these experiments the soil was previously air-dried and sieved before being moistened for use. The results, therefore, may not be comparable to those in natural soil.)

Jordan (43) found that *Esch. coli* in stored normal feces showed an initial increase in number at room temperature and at 37° C., followed by an irregular decline which was more rapid at 37° C. At room temperature the coli disappeared in 36 to 48 days, and in 10 to 20 days at 37° C. When the feces were covered with garden soil or sand, no more rapid decline in *Esch. coli* was noted; on the contrary, with garden soil, an increase in survival was noted. These results should be compared with the survival of *E. typhosa* in feces from typhoid patients and carriers. This was found to have an average maximum longevity of 52 days with no multiplication noticeable.

Kulp (50) studied the viability of 15 strains of *Esch. coli* and 9 strains of *Aer. aerogenes* in sterilized garden soil. Six strains of the former and two of the latter were still viable after 3.5 years.

Parr (68) found coli groups most predominant in fresh feces, but these were replaced by aerogenes types in 2 months at 37° C. The change-over was more rapid in lower temperatures.

Mudd (63), on a recent tour of Soviet laboratories, noted that their work indicated a complete absence of both *Esch. coli* and *Aer. aerogenes* in soils not polluted by humans and other animals. Thus, both were considered indicators of some sort of pollution. Also, the thermophilic organisms resulting from human fecal pollution have a lower temperature tolerance (up to 60° C.), where those from some animal feces tolerate 60° C. and above.

Ostrolenk, Kramer, and Cleverdon (66) compared survivals of *Esch. coli* and enterococci in virgin and contaminated soils at room temperature and at 45° F. (7.2° C.). Survival was favored by the lower temperature. In the unfertilized soil, the enterococci survived longer than the coli, whereas survival was less than or equal to that of the coli in the soil contaminated with chicken manure or artificially contaminated with organisms.

Using *Esch. coli* as an indicator organism, Champion and Van de Velde (15a) found that strawberries, lettuce, and carrots rinsed in a 0.2 per cent solution of chlorinated lime were reasonably well, but not completely, disinfected. After 0.5 hr. contact, *Esch. coli* was destroyed and the total number of bacteria was reduced, sometimes to zero. Taste and smell were but slightly, if at all, modified.

In South Africa, from watercress grown in a sewage (trickling filter) effluent, Hogg (39) showed *Esch. coli* present in 1 ml. or less of the final wash water, even after three washings with sterile water. At a concentration of 0.25 per cent, bleaching powder was effective in killing the organisms after 10 min. soaking without wilting leaves or leaving tastes. Potassium permanganate ($\frac{1}{80}$ N) was not effective, whereas 2 per cent sodium chloride was ineffective and wilted the leaves.

In water under starvation conditions, Hinds (38) found that oxygen appeared to be harmful to *Esch. coli* and beneficial to *E. typhosa*.

Winslow and Cohen (108) found that mixtures of coli and aerogenes organisms in water gave 98 to 99 per cent reduction in 10 days. The coli death rate was higher except during the first 24 hr. when the reverse was true. Winslow and Brooke (107) found that when *Esch. coli* cultures were suspended in distilled water (after being centrifuged twice to remove substances carried over from culture media) the organism survived several hours. Other organisms (as *B. cereus, megatherium,* and *prodigiosus*) died off to less than 1 per cent in 1 hr. Without centrifugation the bacteria do not die off so rapidly, indicating either a protective action of the organic material adhering to the cells or the carrying over of nutrient material, which can support the population for a time.

Heukelekian (35) studied the fate of *Esch. coli* and *Aer. aerogenes* in a trickling filter sewage treatment plant equipped with Imhoff tanks. No appreciable reduction took place in the Imhoff and secondary settling tanks, but the bacteria were reduced by 89 per cent when passing through the filter bed. When fresh sewage solids are subjected to anaerobic digestion without seeding with ripe anaerobic sludge, the organisms were found to rise to a maximum in about two days and then rapidly decline to a low level. Heukelekian and Rudolfs (37) found that aerating sewage produced a temporary increase of *Esch. coli*, probably due to breaking up of colloidal aggregates and bacterial clumps.

Sherman and Cameron (88) noticed that young cells of *Esch. coli* may be killed by abrupt changes in the environment, even though maintained within the natural limits of growth.

Such changes as raising or lowering temperature and osmotic pressures are cited. This was also confirmed by Hegarty and Weeks (34).

Platt (72) studied the viability of coli and aerogenes in sterile and raw river waters at 0°, 18°, and 37° C. In general, aerogenes were more resistant than coli at 18° C., but the reverse was true at 0° and 37° C. In sterile water at 0° C., both organisms decreased slowly, but only coli were present after 73 days. At 18° C. in the dark there was a slight increase in number for the first few days, but then both declined at the same rate. In diffused sunlight the coli disappeared in 60 days, whereas the aerogenes multiplied tenfold. At 37° C., aerogenes died off in 1 to 4 days and coli in 26 to 30 days.

Parr (69) found that *Esch. coli* isolated from feces was re-isolated from sterilized tap water after 2.5 years in an icebox. He concluded that *Esch. coli*, as well as *Aer. aerogenes*, could remain viable for long periods in various environments.

In a summing up of the survival of the colon-aerogenes group reported in various investigations above, several important factors appear.

1. In natural soils, *Esch. coli*, as well as *Aer. aerogenes*, can survive for long periods, longer than the average time for the survival of *E. typhosa* in similar environments.

2. The viability of *Esch. coli* in feces is not as great as in soil, probably because of the high organic content of the former supporting a large population of other types of microorganisms.

3. As in the case of *E. typhosa*, lower temperatures appear to favor increased survival.

4. The use of *Esch. coli* as a bacterial indicator of the effectiveness or completeness of cleaning or sterilization of raw fruits and vegetables will probably be useful. However, as it apparently survives longer in soil than most pathogenic intestinal bacteria, to await the death of all or most *Esch. coli* before considering a soil no longer capable of carrying disease organisms may prove to be too extreme a test.

Vibrio Cholera

Cholera has long been a problem in many parts of the world. However, the fate of the causative organism in natural environments other than the human being has not been studied extensively.

Abdou (1) held that the Egyptian cholera epidemic of 1947, which produced 20,877 cases with 10,265 deaths, was spread to neighboring areas through the consumption of ripe dates harvested in the area where the disease first appeared. He based this conclusion on circumstantial evidence and the fact that "it has been proved in Iraq that the cholera vibrio cannot live in compressed dates, owing to the high concentration of sugar, but it can live on the skin of ripe dates for some time."

On the other hand, other descriptions of the epidemic (3) (110) do not mention this method of transmission. World Health Organization (WHO) makes the point that "the disease has failed to establish itself in any of the towns provided with satisfactory water supplies and adequate sewage disposal systems, in spite of repeated introduction from the villages." Were dates the principal vectors, the incidence of disease would be largely independent of water supply sanitation.

Flu (26) (27) compared the survival of the cholera vibrio with that of typhoid organisms in reservoirs and septic tanks. In both environments the cholera organism was found to die out in 2 to 5 days, whereas the typhoid organism was gone in 7 to 8 days. The survival was less in septic tanks than in reservoirs.

Courmont, Rochaix, and Lanpin (18) found that cholera vibrio did not survive activated sludge (6-hr. aeration), but organisms of the typhoid-

paratyphoid group were found in the effluent after similar treatment.

Yasuhara (111) tested the longevity of the cholera vibrio in infected water under Japanese winter conditions (morning temperature, 1° to 5° C.). His results were as follows:

Sea water	11 days
Sea and river water mixed	13 days
River water	8 days
Tap water	8 days
Well water	6 days

On the basis of his results he suggested that water known to be contaminated with the vibrio be stored two weeks before use.

Further work by Kiribayashi and Aida (46) on the fate of this organism in sea water indicated an average survival of 10 days. Survival was longer in sterilized sea water.

Lahiri, Das, and Malik (51a) studied the viability of the cholera organisms in spring, tap, river, and surface tank waters in Calcutta. The organism was viable from 1 to 72 hr. in the raw waters, but lived as long as 18 days in sterile waters.

In summary, the transmission of cholera by the consumption of raw vegetables is in doubt. No clearcut cases of transmission of the disease by this method have been found. The viability of cholera bacteria, like that of *E. typhosa* and *Esch. coli*, is longer in a sterile environment than in a natural one. Also, the durability of the cholera bacteria is not as great as that of either of the other two organisms under both natural and sterile conditions.

Miscellaneous Bacteria

Steuer (92) investigated the viability of the organism of bacillary dysentery in polluted well water in Poland. Tests at 37° C., at room temperature, and at −3° C. showed survival time to be variable, but longer at lower temperatures. At room temperature survival was for several days, sometimes more than one week.

Savage and Wood (83) compared the survival of streptococci with *Esch. coli* in sterile and polluted water. In the former, the streptococci died off rapidly (about two weeks), whereas the coli increased in number. In sewage and polluted water, the coli also survived for a longer period.

Livingston (54) studied the viability of 11 strains of *Str. hemolyticus* and one of *Str. viridans* in water. The former showed survivals in distilled water of from 3 to 87 days, averaging 38, whereas *viridans* survived 50 days. Factors which tended to increase survival time were higher initial streptococcus concentrations, lower temperature, greater sterility, and purity of the water. Avirulent strains survived longer than virulent strains.

The viability of bovine tubercle bacilli in cows' feces has been studied by Williams and Hoy (104). Under climatic conditions of southern England the organisms could survive for at least 5 months in winter, 2 in spring and 4 in autumn, but not longer than 2 months in summer.

Maddock (57) found that addition of dung to soil favored survival of the bovine tubercle bacillus. Positive tests for the organism (on basis of animal inoculation) were obtained from soil and manure up to 178 days; on grass, survival was 49 days, possibly longer.

Rhines (74) found that an avian strain of the tubercle bacillus was able to survive for longer periods in natural and in toluene-sterilized soil. The presence of other general soil bacteria, fungi, and actinomycetes did not strongly depress the number of tubercle bacilli. Death rates were similarly slow in sewage.

More recently, Jensen and Jensen (42) found virulent tubercle bacilli in the effluent of well-constructed sewage plants at tuberculosis sanitoria. Sludge a year old was found high in tubercle bacilli. Thus, the use of this sludge as fertilizer before the tubercle organisms had been killed by proper treat-

ment was considered objectionable. Chlorination of an activated sludge effluent with 10 p.p.m. of chlorine was sufficient to kill the remaining tubercle bacilli.

Kraus (49) investigated the cause of illness of cattle watered from a pond receiving the effluent from a tuberculosis sanitarium. Although the report does not actually state the illness to be tuberculosis, the results showed that tubercle bacilli in the sewage came from water closets and an inefficient sputum sterilizing apparatus. Tubercle bacilli were demonstrated, in diminishing numbers, throughout the dispersion system and on grass and soil as much as 10 miles downstream from the final outfall. However, they were not demonstrated in stream water 150 miles distant.

Crawford and Frank (19) experimented on the feeding of sewage and sludge to pigs and cattle. The sewage was obtained from the treatment plant of an agricultural experiment station where studies on animal diseases included tuberculosis, brucellosis of cattle and swine, infectious anemia of horses, equine encephalomyelitis, mastitis of cattle, hog cholera, swine erysipeles, vesicular stomatitis, and other bacterial and virus diseases. The sewage was treated by sedimentation, trickling filters, separate sludge digestion, and chlorination. Although some of the material from diseased animals was sterilized before entering the sewerage system, a great amount of viable material from laboratories, autopsy room, etc. gained access to the system.

Cattle and hogs were fed raw sewage, plant effluent, and digested sludge mixed with feed over a period of one summer. All animals gained weight normally, at no time indicating signs of sickness or loss of appetite. Tuberculin tests were always negative during feedings and several months afterward. The slaughtered animals showed no evidence of disease on post-mortem examination.

The authors concluded that "virulent bacteria are not present in sufficient concentration in the incoming sewage, effluent, and sludge to cause disease in susceptible animals. It is believed that test animals in this experiment were subjected to a more severe exposure to the effluent than would ordinarily occur in livestock below a modern-type sewage treatment plant."

Virus Diseases (Poliomyelitis)

Although neither the mode of transmission of infantile paralysis nor the role of sewage, water supplies, and food contamination has ever been clearly established, a brief review of some recent literature on poliomyelitis in sewage and water should be presented.

Among reports of the presence of poliomyelitis in sewage the findings of Trask and Paul (98) and Mundal, Gear, and Wilson (64) may be mentioned. Trask and Paul investigated the sewages of New York City and New Haven, Conn., finding the virus present, but not during non-epidemic periods. Mundal *et al.* (64), who studied the distribution of the virus in the Johannesburg, South Africa, sewage treatment works, found the virus in settled sewage, but not in digested sludge or sand filter effluents or in psychoda flies associated with the plant. However, no case of poliomyelitis had been reported for the previous two months in the area served; the finding of the virus in settled sewage might possibly indicate that continued infection was still occurring.

Carlson, Ridenour, and McKhann (14) studied the efficiency of present water purification methods in removing the poliomyelitis virus. In increasing efficiency, the methods are coagulation with alum and lime and sedimentation, sand filtration, and activated charcoal; ultraviolet irradiation was better than direct sunlight. The virus was 40 per cent viable in tap water

after 100 days in a refrigerator. In further work, these authors (15) indicated that activated sludge concentrations of 1,100 p.p.m. largely removed the virus from sewage after 6-hr. aeration. Increasing sludge concentrations up to 3,300 p.p.m. removed the virus sufficiently from the liquor to make it almost completely non-infectious. A mouse-adapted strain was used in the work.

Lensen, Rhian, and Stebbins (52) studied the effect of chlorination on the inactivation of a mouse-adapted strain of virus in water. Free chlorine, or chlorine and chloramine, in total residuals of 0.3 to 0.5 p.p.m. were usually sufficient to inactivate 0.25 and 0.5 per cent virus suspensions.

Summary on Bacteria and Virus Diseases

The following general points have been brought out by the literature survey presented.

1. Raw fruits and vegetables growing in infected soil can be contaminated with pathogenic bacteria.

2. Such infected vegetation may be difficult to clean and disinfect, especially where injured or broken parts are concerned.

3. Among the factors influencing the survival of intestinal pathogenic bacteria in soil and on vegetation are the following:

a) Type of organism—*Esch. coli*, *E. typhosa*, and *M. tuberculosis* appear to be most resistant.

b) Temperature—lower temperature increases viability.

c) Moisture—longevity is greater in moist soil than in dry soil.

d) Type of soil—neutral, high-moisture-holding soils favor longevity.

e) Organic matter—the type and amount of organic matter present may serve as a food and energy source to sustain or allow bacteria to increase.

f) The presence of other microorganisms has an influence on the pathogenic organisms. This has been illustrated repeatedly by longer survival after inoculation of a pathogen into a sterilized soil, sewage, or water than into a corresponding non-sterile substrate.

4. Among the most common intestinal-disease and nonpathogenic bacteria, *Eberthella typhosa*, *Mycobacterium tuberculosis* and *Escherichia coli* appear to be the most resistant to natural conditions outside the human body. Also, with the exception of *M. tuberculosis*, these have been studied the most extensively. Furthermore, the methods for isolating *Esch. coli* and *E. typhosa* in soil, sewage, and water have reached higher development.

5. As a whole, the literature leaves the impression that *Esch. coli* is more resistant that *E. typhosa* in soils, sewage, and water.

References

1. Abdou, S., "The Cholera Epidemic in Egypt. Mode of Spread." *Lancet*, **2**, 696 (Nov. 8, 1947).
2. Anon., "Typhoid Fever in Paris." *Jour.*, Am. Med. Assoc., **80**, 1628 (1923).
3. Anon., "Anti-Cholera Measures in Egypt." *Lancet*, **2**, 697 (Nov. 8, 1947).
4. Arnold, L., "The Significance of Bacteriophage in Surface Water." *Am. Jour. Pub. Health*, **15**, 950 (1925).
5. Ballantyne, E. N., "On Certain Factors Influencing the Survival of Bacteria in Water and in Saline Solutions." *Jour. Bact.*, **19**, 303 (1930).
6. Beard, P. J., "The Survival of Typhoid in Nature." *Jour.*, Am. Water Works Assoc., **30**, 124 (1938).
7. Beard, P. J., "Longevity of *Eberthella typhosus* in Various Soils." *Am. Jour. Pub. Health*, **30**, 1077 (1940).
8. Beard, P. J., Carlson, J. M., and Chambers, R. D., "The Survival of *E. typhosa* in Soil." *Jour. Bact.*, **33**, 74 (1937).
9. Beard, P. J., and Meadowcroft, N. F., "Survival and Rate of Death of In-

testinal Bacteria in Sea Water." *Am. Jour. Pub. Health*, **25**, 1023 (1935).

10. Begbie, R. S., and Gibson, H. J., "Occurrence of Typhoid-Paratyphoid Bacilli in Sewage." *Brit. Med. Jour.* (July 12, 1930); *Analyst*, **55**, 593 (1930). Cited Ruehhoft (78).
11. Bruns, H., and Sierp, F., "The Effect of the Activation of Sewage Sludge on Pathogenic Organisms." *Zeit. Hyg. Infect.-Krankh.*, **107**, No. 3-4 (1927).
12. Butterfield, C. T., and Wattie, E., "Influence of pH and Temperature on the Survival of Coliforms and Enteric Pathogens when Exposed to Chloramine." *U. S. Pub. Health Rep.*, **61**, 157 (1946).
13. Butterfield, C. T., Wattie, E., Magregian, S., and Chambers, C. W., "Influence of pH and Temperature on the Survival of Coliforms and Enteric Pathogens When Exposed to Free Chlorine." *U. S. Pub. Health Rep.*, **58**, 1837 (1943).
14. Carlson, H. J., Ridenour, G. M., and McKhann, C. F., "Efficiency of Standard Purification Methods in Removing Poliomyelitis Virus from Water." *Am. Jour. Pub. Health*, **32**, 1256 (1942).
15. Carlson, H. J., Ridenour, C. M., and McKhann, G. F., "Effect of the Activated Sludge Process of Sewage Treatment on Poliomyelitis Virus." *Am. Jour. Pub. Health*, **33**, 1083 (1943).

15a. Champion and Van de Velde, "Chlorinated Lime as a Bactericide for Raw Fruits and Vegetables." (Soc. de Med. de Ghent) *Jour.*, Am. Med. Assoc., **76**, 1511 (1921).

16. Chapman, E. W., "Sewage Contaminated Irrigation Water." *Am. Jour. Pub. Health*, **25**, 930 (1935).
17. Cohen, B., "Disinfection Studies." *Jour. Bact.*, **7**, 183 (1922).
18. Courmont, P., Rochaix, A., and Lanpin, F., "Disappearance of Pathogenic Germs During the Purification of Activated Sludge." *Jour.*, Soc. Chem. Ind., **40**, 600A (1921).
19. Crawford, A. B., and Frank, A. H., "Effect on Animal Health of Feeding Sewage." *Civ. Eng.*, **10**, 495 (1940).
20. Creel, R. H., "Vegetables as a Possible Factor in the Dissemination of Typhoid." *U. S. Pub. Health Rep.* **27**, 187 (1912).
21. Demster, *Brit. Med. Jour.*, **1**, 1126 (1894).
22. Edwards, G. P., "The Effect of Activated Sludge on Pathogenic Organisms." *Sewage Works Jour.*, **2**, 292 (1930).
23. Fehrs, "Die Beeinflussung der Lebensdauer von Krankheitskeimen in Wasser durch Protozoan." *Hyg. Rundschau*, **16**, 113 (1896). Cited Heukelekian (35).
24. Felsenfield, O., and Young, V. M., "The Viability of Salmonella on Artificially Contaminated Vegetables." *Poultry Science*, **24**, 353 (1945).
25. Firth, R. H., and Horrocks, W. H., "An Inquiry into the Influence of Soil, Fabrics and Flies in the Dissemination of Enteric Infection." *Brit. Med. Jour.*, **2**, 936 (1902). Cited Tanner (97).
26. Flu, P. C., "Investigations of the Duration of Life of Cholera Vibriones and Typhoid Bacteria in Septic Tanks at Batavia." *Med. Burg. Geneesk. Dienst*, 179 (1921).
27. Flu, P. C., "Investigations of the Auto-Purification of Water in Large Reservoirs Exposed to the Direct Rays of the Sun." *Med. Burg. Geneesk. Dienst*, 299 (1921).
28. Frankland, P., "The Bacteriology of Water: Its Present Position." *Jour.*, Soc. Chem. Indust., **30**, 319 (1911).
29. Galvagne and Calderini, *Zeit. f. Hyg.*, **61**, 188 (1908). Cited Creel (20).
30. Granger, J., and Deschamps, E., *Arch. de Med. Exper. et D'Anat. Path.*, **1**, 33 (1889). Cited Beard (6).
31. Gray, A., "The Isolation of *B. paratyphosus B* from Sewage." *Brit. Med. Jour.*, 3551 (Jan. 26, 1929).
32. Green, C. E., and Beard, P. J., "The Survival of *E. typhi* in Sewage Treatment Plant Processes." *Am. Jour. Pub. Health*, **28**, 762 (1938).
33. Hajna, A. A., "Isolating Typhoid Bacilli in Sewage." *Mun. Sanit.* **6**, 234 (1935).
34. Hegarty, C. P., and Weeks, O. B., "Sensitivity of *E. coli* to Cold-Shock During Logarithmic Growth Phase." *Jour. Bact.*, **39**, 475 (1940).
35. Heukelekian, H., "The Fate of *B. coli* and *B. aerogenes* in Sewage Purification." *Jour. Bact.*, **14**, 55 (1927).
36. Heukelekian, H., and Schulhoff, H. B., "Studies on the Survival of *B. typhosus* in Surface Waters and Sewage." *N. J. Agr. Exp. Sta. Bull.*, 589 (1935).
37. Heukelekian, H., and Rudolfs, W., "Effect of Aeration and Protozoa on *B. coli* in Sewage." *Sewage Works Jour.*, **1**, 561 (1929).
38. Hinds, M. E., "The Factors Which Influence the Longevity of *B. coli* and *B. typhosus* in Water." *Univ. Ill. Bull.*, **14**, Water Survey Series, **13**, 225 (1932).

39. Hogg, E. S., "The Washing of Watercress Grown in Sewage Effluent." *Jour. and Proc.*, Inst. Sew. Purif., 239 (1944).
40. Hoskins, J. K., "Bacterial Purification Rates in Polluted Water." *U. S. Pub. Health Rep.*, **50**, 385 (1935).
41. Houston, A. C., "Studies in Water Supply." MacMillan and Co., London (1913).
42. Jensen, K. A., and Jensen, K. E., "Occurrence of Tubercle Bacilli in Sewage and Experiments on Sterilization of Tubercle Bacilli-Containing Sewage with Chlorine." *Acta. Tub. Scand.*, **16**, 217 (1942).
43. Jordan, E. O., "The Changes in Bacterial Content of Stored Normal and Typhoid Feces." *Jour. Infect. Dis.*, **38**, 306 (1926).
44. Jordan, E. O., Russell, J. L., and Zeit, F. R., "The Longevity of the Typhoid Bacillus in Water." *Jour. Infect. Dis.*, **1**, 641 (1904).
45. Karlinski, J., *Cent. f. Bakt.*, **65** (1889); *Arch. f. Hyg.*, **13**, 302 (1891). Cited Beard (6).
46. Kiribayashi, S., and Aida, T., "A Study of the Fate of Cholera Vibrios in the Sea Water of Keeling Port, Formosa." *Jour.*, Public Health Assoc. (Japan), **9**, 11, 1 (1933).
47. Kligler, I. J., "Investigations of Soil Pollution and the Relation of the Various Types of Privies to the Spread of Intestinal Infections." International Health Board, Monograph 15, Rockefeller Inst. of Med. Res., p. 1 (Oct. 10, 1921).
48. Kozyn, M. B., "Bacteriological Studies of Field-Grown Vegetables from Moscow." *Vrach* (St. Petersburg), **22** (1907); *E. S. R.*, **20**, 64 (1908–9). Cited Tanner (97).
49. Kraus, E., "Studies of the Spreading of Tubercle Bacilli from the Sewage of a Sanatorium." *Arch. Hyg. u. Bakt.*, **128**, 112 (1942).
50. Kulp, W. L., "A Note Concerning the Effect of a Specific Environment on the Characteristics and Viability of Several Strains of *A. aerogenes* and *E. coli*." *Jour. Bact.*, **24**, 317 (1932).
51. Kyriasides, K., "Experiments on the Importance of Protoza in the Self-Purification of Water." *Gas-und Wasserfach*, **74**, 891 (1931).
51a. Lahiri, M. N., Das, P. C., and Malik, K. S., "The Viability of Vibrio Cholerae in Natural Waters." *Indian Med. Gaz.*, **74**, 742 (1939); *Pub. Health Eng.*, **20**, 11, 40 (1940).
52. Lensen, S. G., Rhian, M., and Stebbins, M. R., "The Inactivation of Partially Purified Poliomyelitis Virus in Water by Chlorination." *Jour.*, Am. Water Works Assoc., **38**, 1069 (1946).
53. Levy and Kayser, *Cent. f. Bakt.* **33**, 489 (1903). Cited Creel (20).
54. Livingston, G. S., "The Vitality and Viability of Hemolytic Streptococci in Water." *Am. Jour. Hyg.*, **1**, 239 (1921).
55. Loots, J. N., "Diseases Liable to be Spread by the Present Methods of Disposal of Municipal Night Soil, Refuse and Abattoir Wastes." *Pub. Health* (South Africa) (Apr., 1943). Cited Wilson (105).
56. Lumsden, L. L., and Anderson, J. F., "The Origin and Prevention of Typhoid in the District of Columbia." Bull., Hyg. Lab., 78 (1909–10).
57. Maddock, E. C. G., "Studies on the Survival Time of the Bovine Tubercle Bacillus in Soils, Soil and Dung, in Dung, and on Grass." *Jour. Hyg.*, **33**, 103 (1933).
58. Martin, S., Annual Reports of the Medical Officer of the Local Government Board (1897–1900).
59. McCloskey, C. S., and Christopher, W. N., "The Longevity of Certain Pathogenic Bacteria in Strawberries." *Jour. Bact.*, **41**, 98 (1941).
60. Melick, C. O., "The Possibility of Typhoid Infection through Vegetables." *Jour. Infect. Dis.*, **21**, 28 (1917).
61. Mills, R., Bartlett, C. L., and Kessel, J. F., "The Penetration of Fruits and Vegetables by Bacteria and other Particulate Matter, and the Resistance of Bacteria, Protozoan Cysts, and Helminth Ova to Common Disinfection Methods." *Am. Jour. Hyg.*, **5**, 559 (1925).
62. Mom, C. P., and Schaeffer, C. O., "Typhoid Bacteria in Sewage and in Sludge—An investigation into the Hygienic Significance of Sewage Purification in the Tropics with Respect to Typhoid Fever." *Sewage Works Jour.*, **12**, 715 (1940).
63. Mudd, S., "Programs for Medicine and National Health in the U. S. S. R." *Science*, **105**, 269 (1947).
64. Mundal, B., Gear, J., and Wilson, D., "The Distribution of Virus of Poliomyelitis in a Sewage Purification Works in Johannesburg." *South African Med. Jour.*, **20**, 336 (1946).
65. Murillo, F., "Cholera, Typhoid and Vegetables." *Plus Ultra* (Madrid), **2**, 115 (1919). Cited Tanner (97).
66. Ostrolenk, M., Kramer, N., and Cleverdon, R. C., "Comparative Studies of *Enterococci* and *Escherichia coli* as In-

dices of Pollution." *Jour. Bact.*, **53**, 197 (1947).

67. Papenberg, H., "Investigation of Bacteria of the Paratyphoid Enteritis Group in the Sewage of Greater Berlin." Inaug. dissertation, Berlin (1935).
68. Parr, L. W., "The Sanitary Significance of the Succession of Coli-Aerogenes Organisms in Fresh and Stored Feces." *Am. Jour. Pub. Health*, **26**, 39 (1936).
69. Parr, L. W., "The Viability of Coli-Aerogenes Organisms in Culture and in Various Environments." *Jour. Infect. Dis.*, **60**, 291 (1937).
70. Pasricha, C. L., and Paul, B. M., "Bacteriophage in Soil." *Indian Med. Gaz.*, **76**, 416 (1941).
71. Pesch, K. L., and Sauerborn, E., "Chemical and Bacteriological Sewage Investigations." *Ges. Ing.*, **52**, 856 (1929).
72. Platt, A. D., "The Viability of *B. coli* and *B. aerogenes in Water*." *Am. Jour. Hyg.*, **35**, 437 (1935).
73. Remlingen, P., and Nouri, O., "Lee Microbes Pathogenes du Sol Peuvent-ils Penetrer a L'interieur des Vegetauz." *Comp. Rend. Soc. Biol.*, **67**, 646 (1909).
74. Rhines, C., "Studies on the Persistence of Avian Tubercle Bacilli in Soil and on the Relationship of Soil Microorganisms to the Tubercle Bacilli." Ph.D. thesis, Rutgers Univ. (June, 1935).
75. Robertson, *Brit. Med. Jour.*, **1**, 69 (1898).
76. Rochaix, A., "Experiments on the Persistence and Disappearance of Pathogenic Bacteria in Sewage." *Ann. D'Hyg.*, **8**, 569 (1930).
77. Rubentschik, L., Roison, M. B., and Bieljanksy, F. M., "Adsorption of Bacteria in Salt Lakes." *Jour. Bact.*, **32**, 11 (1936).
78. Ruchhoft, C. C., "Studies on the Longevity of *B. typhosus* in Sewage Sludge." *Sewage Works Jour.*, **6**, 1054 (1934).
79. Ruediger, G. F., "Studies on the Self-Purification of Streams." *Am. Jour. Pub. Health*, **1**, 411 (1911).
80. Rullman, *Cent. f. Bakt.*, **30**, 321 (1901).
81. Russell, H. L., and Fuller, C. A., "The Longevity of *B. typhosus* in Natural Water and Sewage." *Jour. Infect. Dis.*, Sup., **2**, 40 (1905).
82. Ruys, A. C. *Proc.*, Roy. Acad. (Amsterdam), **39**, 780 (1936). Cited Mom and Schaeffer (62).
83. Savage, W. G., and Wood, D. R., "The Vitality and Viability of *Streptococci* in Water." *Am. Jour. Hyg.*, **16**, 227 (1917).
84. Schaeffer, C. O., "Investigation of the Occurrence of Typhoid Bacteria in Sewage at Jogjakarta and Their Behavior During Settling and Biological Purification." *Meded, Dienst der Volks.* (Nederl.-Indie), **29**, 49 (1940).
85. Schaeffer, C. O., "Typhoid Bacilli in the Sewage System of Bandoeng." *Geneesk. Tijdschr.* (Nederl.-Indie), **81**, 1535 (1941); *Trop. Dis. Bull.*, **39**, 197 (1942).
86. Scott, R. D., and McClure, G. M., "The Hydrogen-Ion Concentration of Lime Treated Water and Its Effect on Bacteria of the Colon-Typhoid Group." *Jour.*, Am. Water Works Assoc., **11**, 578 (1924).
87. Sedgwick, W. T., and Winslow, C. E. A. *Mem.*, Amer. Acad. Arts and Sci., **12**, 508 (1902).
88. Sherman, J. M., and Cameron, G. M., "Lethal Environmental Factors Within the Natural Range of Growth." *Jour. Bact.*, **27**, 341 (1934).
89. Shimomura, H. J., "Experimental Studies on the Survival of *B. typhosus* in the Sewerage Water of Taihoka City (Formosa)." *Jour.*, Med. Assoc. of Formosa, **34**, 1294 (1935).
90. Skinner, C. E., and Murray, T. J., "The Viability of *B. coli* and *B. aerogenes* in Soil." *Jour. Infect. Dis.*, **38**, 37 (1926).
91. Smith, J. L., "An Investigation into the Conditions Affecting the Occurrence of Typhoid Fever in Belfast." *Jour. Hyg.*, **4**, 407 (1904).
92. Steuer, W., "The Viability of Dysentery Bacteria in Well Water." *Arch. Hyg.* (Berlin), **126**, 228 (1941); *Pub. Health Eng. Abs.*, **23**, 4, 32 (1943).
93. Stewart, A. D., and Chosal, S. C., "The Bacterial Effect of Sewage Treatment with Activated Sludge." *Indian Jour. Med. Res.*, **16**, 989 (1929).
94. Stewart, A. D., and Chosal, S. C., *Indian Jour. of Med. Res.*, **20**, 341 (1932). Cited Mom and Schaeffer (62).
95. Stokes, E. J., Jones, E. E., and Miles, A. A., "Effect of Drying and Digestion of Sewage Sludge on Certain Pathogenic Organisms." *Jour. and Proc.*, Inst. Sew. Purif., Part I, 36 (1945).
96. Suzuki, S., "Effect of Bleaching Powder on Typhoid Bacilli Attached to Vegetables." *Jour.*, Pub. Health Assoc. (Japan), **6**, 8 (1930).
97. Tanner, F. W., "Public Health Significance of Sewage Sludge When Used as a Fertilizer." *Sewage Works Jour.*, **7**, 611 (1935).
98. Trask, J. D., and Paul, J. R., "Periodic Examination of Sewage for the Virus

of Poliomyelitis." *Jour. Exp. Med.*, **75**, 1 (1942).

99. Wattie, E., and Butterfield, C. T., "Relative Resistance of *Escherichia coli* and *Eberthella typhosa* to Chlorine and Chloramine." *U. S. Pub. Health Rep.*, **59**, 1661 (1944).
100. Wattie, E., and Chambers, C. W., "Relative Resistance of Coliform Organisms and Certain Enteric Pathogens to Excess-Lime Treatment." *Jour.*, Am. Water Works Assoc., **36**, 709 (1943).
101. Wheeler, J. M., "The Viability of *B. typhosus* under Various Conditions." *Jour. Med. Res.*, **15**, 269 (1906).
102. Whipple, G. C., and Mayer, A., "On the Relation Between Oxygen in Water and the Longevity of the Typhoid Bacillus." *Jour. Infect. Dis.*, Sup., **2**, 76 (1906).
103. Wibaut, N. L., and Moens, S., "The Disappearance of Typhoid Bacteria in Water." *Verslag.*, Natvurk. Konink Akad. Watensch, **36**, 1, 129 (1927).
104. Williams, R. S., and Hoy, W. A. *Jour. Hyg.*, **30**, 413 (1930).
105. Wilson, H., "Risks of Transmission of Disease Through the Use of Sewage Sludge as Fertilizer." Paper presented at Conference on Utilization of Sewage Sludges, Inst. Sew. Purif. Pretoria, South Africa (Nov., 1948).
106. Wilson, W. J., and Blair, E. M., "Further Experience of the Bismuth Sulfite Media in the Isolation of *Bacillus typhosus* and *B. paratyphosus B* from Feces, Sewage and Water." *Jour. Hyg.*, **31**, 138 (1931).
107. Winslow, E. E. A., and Brooke, O. R., "The Viability of Various Species of Bacteria in Aqueous Suspensions." *Jour. Bact.*, **13**, 235 (1927).
108. Winslow, G. C. A., and Cohen, B., "The Relative Viability of *B. coli* and *aerogenes* in Water." *Jour. Infect. Dis.*, **23**, 82 (1918).
109. Wolman, A., "Hygienic Aspects of Sewage Sludge as Fertilizer." *Eng. News-Rec.*, **92**, 198 (1924).
110. World Health Organization, "Cholera in Egypt." *Chronicle*, **1**, 157 (1947); *Trop. Dis. Bull.*, **45**, 333 (1948).
111. Yasuhara, S., "How Long Does *Cholera vibrio* Live in the Water in Winter?" *Jour.*, Pub. Health Assoc. (Japan), **2**, 9, 1 (1926).
112. Young, C. C., and Greenfield, M., "Observations on the Viability of the *Bacterium coli* Growing under Natural and Artificial Conditions." *Am. Jour. Pub. Health*, **13**, 270 (1923).

Additional References

Dyer, B. R., and Bhaskaran, T. R., "The Present State of Our Knowledge of Soil and Ground Water Pollution." *Indian Med. Gaz.*, **78**, 561 (1943); *U. S. Pub. Health Eng. Abs.*, **24**, 8, 32 (1944).

Falk, L. L., "Factors Affecting the Contamination and Decontamination of Raw Tomatoes with Reference to Tomatoes grown in Polluted Soil or Contaminated in the Laboratory by Coliform or Helminth Organisms." Ph.D. thesis, Rutgers Univ. (1949).

Falk, L. L., "Bacterial Contamination of Tomatoes Grown in Polluted Soil." *Am. Jour. of Pub. Health*, **39**, 1338 (1949).

Kehr, R. W., and Butterfield, C. T., "Notes on the Relation between Coliforms and Enteric Pathogens." *U. S. Pub. Health Rep.*, **58**, 589 (1943).

Maxcy, K. F., and Howe, H. A., "The Significance of the Findings of the Virus of Infantile Paralysis in Sewage." *Sewage Works Jour.*, **15**, 1101 (1943).

Ragotzkie, R. A., "The Significance in Crop Contamination of the Survival of Certain Enteric Bacteria and *Endamoeba histolytica Cysts.*" M.S. thesis, Rutgers Univ. (1950).

Vacek, B., "Examination of Some Conditions Necessary for the Survival of the Typhoid Bacillus in Water." *Cent. f. Bakt.*, **107**, 485 (1932).

Wilson, H., "Some Risks of Transmission of Disease During the Treatment, Disposal and Utilization of Sewage, Sewage Effluent and Sewage Sludge." *Jour. and Proc.*, Inst. Sew. Purif., 214 (1944).

Wilson, H., "Diseases from Sewage—Risks of Transmission of Disease during the Conveyance, Treatment, Disposal and Utilization of Sewage." *Pub. Health* (So. Africa), **13**, 11, 332 (Nov., 1949); **13**, 12, 363 (Dec., 1949); **14**, 1, 13 (Jan., 1950); **14**, 2, 45 (Feb., 1950); **14**, 3, 77 (Mar., 1950); **14**, 4, 109 (Apr., 1950); and **14**, 5, 140 (May, 1950).

KEYS TO SUCCESSFUL SEWAGE SERVICES *

By John M. Hepler

Director, Division of Engineering, Michigan Department of Health, Lansing, Mich.

Obviously, the "keys to successful sewage services" discussed in this paper are not physical lock-opening devices. Rather, they are figurative "keys" needed to open the "locks" on the public's appreciation of natural resources, on the community's sense of fairness and justice, and on municipal pocketbooks. By comparison, the figurative "keys" are so important as to far outshadow the others.

As far back as 1925–27 the Michigan Department of Health and the Michigan Department of Conservation tried to open the "bank" of public interest in our lakes and streams. River basins were considered as single units of polluted natural resources and all the cities and villages located on each basin were ordered to obtain reports on methods and costs of removing their contributions to the polluted streams. However, that key did not fit; the reports were received and locked up in the vault of "things to be forgotten."

Then came the depression and the key of "need to make work" did release a few reports and a few dollars from municipal pocketbooks. Many sewer systems were expanded and some treatment plants were built, but there was not present the fundamental desire to reduce pollution as a step to eliminating unhealthful conditions. The construction programs were to make work, not to make things better.

Through that period the Michigan Stream Control Commission was endeavoring to arouse public interest in pollution. Orders were issued; court action was threatened. In a few cases court action was instituted, but still the public appreciation of what was needed was not evident. Orders and court action only created defensive attitudes. The public was not sold on the value of sewage services. There was, however, enough of government sponsored construction to make the picture look rather attractive. In fact, the comment was made that well over 50 per cent of the sewered population of the state was treating its sewage.

Increased Flows

With the advent of World War II there was a vast increase in the quantities of sewage. Housing for war workers added its share; industrial processes, which previously had used some water, were now using large quantities of water. The result was that practically every sewage treatment plant was badly overloaded and tremendous volumes of untreated sewage were going directly to the rivers and lakes. At first this was felt to be strictly due to the war effort, but as reconversion progressed, it was discovered that sewage flows were not returning to their prewar volume, nor anywhere near it. As an example, Lansing has a plant built in 1936 with a 1960 design load of 9 m.g.d. During the war, flows were 15 to 16 m.g.d. and those flows have only dropped to around 12 to 13 m.g.d. since then. This condition can be corroborated by the records of water plants. There must be complete rethinking on the basic data for the design of sewer systems and sewage treatment works. The old

* Presented at 25th Annual Meeting, Michigan Sewage Works and Industrial Wastes Association; Traverse City, Mich.; May 22–24, 1950.

basic 100 g.c.p.d. has gone by the board. Even the smaller villages and cities are finding that 125 to 135 g.c.p.d. is the consumption rate; some municipalities are even claiming rates of 150 to 175 g.c.p.d.

It is the need for taking care of the sewage from previously existing sources, plus the increased sewage flows and the need to prevent still greater deterioration of public waters, that is the incentive behind all of the activities related to stream pollution control today. The Stream Control Commission, the Department of Health, the Department of Conservation, and sportsmen's clubs were among the first to recognize the need. The legislature recognized the situation and established a study committee, which one year later recommended the revision of the Stream Control Act and created the Water Resources Commission. Some municipalities recognized the situation and began to make plans for and build additions to existing plants. A few municipalities recognized the need and started the construction of plants before it became necessary to order them to do so. In general, however, public feeling has not reached that stage where there is a willingness to proceed with pollution abatement measures, although it has reached the stage where many are saying something must be done.

It would be extremely difficult to enumerate specific items or things which have brought public opinion to its present outlook on this subject, but mention must be made of the excellent work of the press in this respect and efforts of the sportsmen's organizations. Somewhere along the line there also has been an entirely new attitude on the part of industry, which is not only spending large sums to treat industrial wastes where methods are known, but also is spending large sums in research trying to find methods of treating wastes for which there is no known treatment.

Financing a Big Problem

It is at this point that the need for the keys becomes apparent. In one respect these keys might be termed the keys to the "how," the "when," and the "where" of the problem. The first key required is the one to the "how," particularly as it applies to the municipal problem. As an example, let it be assumed that for one reason or another the municipal officials have reached that stage where they realize that a treatment works should be built, but how to proceed is the big problem. Attendance at a meeting of the Water Resources Commission would quickly give an appreciation that the problem in their minds is that of finances. Where is the money coming from? It is amazing how many believe that this type of construction can only be done with Federal assistance and they want to know: "Where can we get the Federal money?"; "How soon will Federal money be available?"; and "How much can we get from Federal sources?"

These questions all result from the depression era experience; they have discovered that a smart neighbor got a 55 per cent grant—in a few cases they themselves had the opportunity to get the grant, but their own citizens refused to vote the bonds for the other 45 per cent. Naturally, those who did not build in those days are looking and hoping for the same financial assistance. At the present time there is not one penny available for construction purposes nor is there any indication that there will be any. There is a small amount available for planning purposes, but with Michigan's own postwar planning program and the previous Federal Works planning program, there is not much planning left to be done in Michigan. The stage has been reached where construction can and should commence. How then, to proceed?

An Engineering Problem

To do this job in an orderly, businesslike way, the first thing is to find out what is required and how much it will cost. That is an engineering problem and professional engineering counsel should be obtained. In this connection it is amazing how little apparently is known by municipal officials of the methods for employing engineering counsel. Because they have had no need for such services in the past, even the names of consulting engineers are unknown to them. If such is the case, inquiries should be made from some reliable sources. State agencies dealing with such problems (such as the Water Resources Commission, the State Health Department, and the Municipal Finance Commission) are good sources. Of course, neighboring municipalities known to have had engineering services could also be consulted, or even professional organizations, of which there are several.

The usual procedure after obtaining the names of competent consulting engineers or engineering firms, is to invite them to appear before the municipal officials and discuss their qualifications and, perhaps, offer a tentative contract in which services to be rendered, the compensation to be paid, and other items are set forth. Compensation is usually based on a percentage of the cost of construction of the work planned. Very often, for the initial report a fixed charge is made, which may or may not be credited if detailed plans, construction drawings, specifications, etc., are later ordered. The key at this point is not cheap engineering services, but competent engineering services.

Although many municipal officials do not realize it, it is at this point that the requirements or the desires of such state agencies as the Water Resources Commission and the Health Department are taken care of. There is nothing that definitely requires the engineer to consult with these state agencies, but the engineer invariably does. This is because he knows that, eventually, whatever is planned for construction must meet the approval of these agencies. He does it more particularly because he knows that fundamental data for the basic design of the treatment works can be obtained from these sources.

Of course, there is a lot of other data which must be obtained from municipal records, as well as from careful study of the topography of the area, the population record of the area, the economic development of the area, and the financial situation. Nevertheless, regardless of what data is needed to prepare the report, when it is completed it should present to the municipal officials a complete and concise statement of the problem and how it can be met, what degree of treatment should be provided, and how it can be financed.

With such a report in their hands the municipal officials are then in position to make the all-important decision as to whether or not they will proceed and, if they decide to proceed, how to do it. It is at this point that the problem really begins. Although it is evident that it should be done, there is hesitancy as to whether they should proceed and add taxes or other financial burdens to the citizens of the town. It is at this point that the municipal officials really need help; they admit that it should be done, but they don't know whether to do it or how to do it.

Gaining Public Support

To answer the question of whether to proceed with the project requires a determination of public sentiment. There are numerous ways for determining this. There is always the ballot—a referendum vote can be taken—but sometimes municipal officials have their fingers on the pulse of the population well enough to know that such a vote would be negative. It is at this point

that the local press and local organizations should be vocal. Every effort should be made during this period, when engineering services are employed and the engineer is preparing his report, to mold public opinion in favor of the project. It is something which the State Health Department and Water Resources Commission are ready to do whenever called upon. The public must be told what sewage pollution is doing to the local waterfront and what is happening to the water resources of the state and the nation, to the recreation areas, to real estate, and to industry, as a result of uncontrolled pollution. Particular attention should be paid to informing the public as to the results of local pollution. When businessmen of the town and the women's organizations of the town understand what is happening, they are usually ready and willing to pay their share toward correcting these conditions. When public opinion, as represented in luncheon clubs and other organizations, is aroused, there is little doubt but what the city officials will proceed with the project.

Methods of Financing

To answer the second question of how to proceed is bothersome only because the officials are not familiar with the methods available for such a project. The state legislature has provided all of the legislation needed to finance such a project. Methods are available; it is only a matter of determining which is the best financial method for the particular situation. In this connection, the municipality should have a financial adviser. Some towns have already arranged for this, and it should be noted that such assistance is obtainable in just the same manner as consulting engineering services. It is simply a matter of finding out who are the recognized financial advisers and obtaining their services. In some cases, the financial situation is such that general obligation bonds will provide the financing at the least cost; in others, due to the 15-mill tax limitation and outstanding general obligation bonds, the project will appear to be best handled on a utility basis financed by revenue bonds. In still other cases, a combination of these will appear to be the best solution. In a few cases, usually in urban areas not incorporated, even the county drain law may offer some advantages. It is not intended to discuss these various methods herein, because any one of the methods or combination of the methods cannot be applied to all situations.

One fact that should be emphasized, however, is the soundness and the equity of the revenue bond method of financing. The water system, the telephone system, and the electric light system have always been looked upon as utilities and paid for as used. The sewer system, by a definition of some years ago, is a transportation system taking away from property the used water previously transported to the property. If it is good business to charge by the gallon or the cubic foot for the water delivered to the user, it is equally sound to charge by the same unit for carrying it away and disposing of it after the purchaser is done with it. By this method of financing, it is found that taxes are not affected, the faith and credit of the municipality is not affected, and there is not another item added to the tax burden or squeezed into the 15-mill structure. Revenue bonds are in good standing with investors, and where the financial rating of the municipality is good, favorable interest rates are obtained.

The revenue bond act has another advantage which should be mentioned. If public opinion is right, the governing body is not required to obtain a vote of the electors for authority to proceed. The municipal officials can institute the proceedings purely by a resolution of that body. If there are some who want to object to the action, they can file a petition calling for a referendum, but if no such request is made within 30 days, the municipal of-

ficials can proceed. This is both time saving and money saving; often, time is a definite factor in getting construction underway.

For one reason or another it now appears that the project will proceed and the engineers are instructed to complete the planning documents for construction. This will require some time —often as much as 6 to 9 months for the preparation of the complete plans and specifications. For this reason it is advisable not to delay too long the commissioning of the engineers to do this job. If it is recognized that the job must be done, it is well to have the plan preparation proceed along with the program for educating the public to the need and developing the necessary attitude for favorable consideration of the project by the electorate if a vote is to be taken, or even for educating the public to the idea that they will be paying for sewage service when revenue bonds are to be issued.

State Approval Required

When the plans are completed it is necessary that they be submitted to the State Health Commissioner for his approval. The law specifically charges the State Health Commissioner with the duty of examining the plans with respect to their effect on public health. The plan must meet with his approval before a construction permit is issued. Incidentally, the law specifies that no construction is legally undertaken until such construction permit is obtained and further specifies that it is an illegal act to pay any money for construction, and an illegal act for a contractor to commence construction, until a permit has been issued. This phase of the law was only recently tested in a circuit court in Oakland County, where a well driller was unable to obtain payment for his services for drilling a well because no construction permit had been obtained.

Examination and approval of the plans by the State Health Department is not an examination of plans to determine the strength or adequacy of the structures; the examination comprises a study of the functional design to determine whether or not the plant will do what is required of it and do it in the most economical and satisfactory method. Examination includes such items as determination of settling or detention time, weir overflow rates, adequacy of the secondary treatment, adequacy of chlorination equipment if provided, proper design of the areas in which the operator must work to make sure that health hazards are not created, adequate sludge digestion capacity, proper protective devices on the gas collecting and heating systems, location of valves and other pieces of equipment so that they can be easily and readily operated and inspected. These are some of the items that make for satisfactory operation and satisfied operators. It is surprising how many times in the past, after a plant has been built and placed in operation, the operator will ask why the state authorities approved this or that, the complaint usually being based on an unhandy or inaccessible location of equipment, which prevents him from getting at it easily. This is not a criticism of the designing engineer, because the designing engineer is not primarily interested in operation. It is about the same principle as some of the designs of automobiles, where certain items flow right into the production line and become an integral part of the whole machine, but when a replacement or repair is needed the automobile has to be practically torn apart to get at the item needing attention. When sewage treatment plants are built in such a manner operators are going to neglect those items. The results will not be what was expected of the plant. In reality, it is the State Health Department cooperation with both the designing engineer and the operator that insures maximum efficiency and the greatest return from the dollar invested.

Project Supervision

Following approval of the plans, construction can proceed. In this connection, one item should be specifically mentioned; that is, the purchaser should make sure that the contractor is building the plant in accordance with the plans and specifications. Frequently it is found that the contract between the consulting engineer and the municipality does not specifically include supervision of the project. No project of such magnitude should be built without a resident engineer, representing the city, being on the job throughout the entire construction to see that the best workmanship and material are properly incorporated into the plant.

In connection with construction, consideration should be given to the calendar. In Michigan, winter construction is difficult. A time table providing for much of this preliminary work to be done during the winter so that bids can be advertised and construction started in the early spring, will permit of the most rapid progress being made in the construction.

Sewer Use Control

Another item which should receive municipal consideration during this time is the matter of establishing controls over what the treatment plant is to receive. As long as the sewer system was discharging directly to the river or lake there seemed to be little need for regulating what might be discharged into the system. With the construction of a plant, however, control of the sewage delivered to the plant becomes very essential. Once the plant gets into operation and the public becomes accustomed to the improved condition of the receiving water, any variation will be quickly noted and complained about.

It is, therefore, no longer good politics or good business to accept the wastes of any commercial or industrial establishment until it is known what type of wastes that user is going to discharge into the system. More and more evidence is accumulating that various types of waste are detrimental in the treatment process. A research project is being started at Ohio State University to determine the effects of heavy metals in sewage treatment. A little is known about the action of copper and chromium or chromates, but what about cadmium, nickel, zinc, and other heavy metals which find their way to the sewer system? The effects of cyanides are known. At Battle Creek, Mich., a dump of cyanide waste put one digester completely out of service and greatly reduced the efficiency of a second. Furthermore, those wastes, after passing through the plant, proceeded to kill large quantities of fish in the receiving water.

The answer to the problem is the adoption of ordinances regulating the quantity and the types of wastes which can be discharged to the sewer system for delivery to the treatment plant. Adoption of such ordinances is only good business practice. There is no reason why one tax-paying unit in the municipality should have the right to destroy the total investment by indiscriminate discharge of a waste to the sewer system. A few municipalities have adopted such ordinances. As a part of the report of the International Joint Commission on its study of the pollution of the Detroit River, certain objectives were set up which might be used as the basis for such an ordinance. In addition, the Federation of Sewage Works Associations has published a very valuable pamphlet (1) on the need for such ordinances, with a model to show how such an ordinance should be written and what it should contain. The adoption of such ordinances is becoming essential; no municipality should neglect the adoption of such a protective device to its investment.

Operational Staff

Sometime during the construction of the plant it becomes necessary to give thought to the selection and ap-

pointment of a staff to operate it. Here again, past practices of staff selection are deplored. In this connection, specific attention is called to some of the previous remarks relative to a sewage treatment works being a type of business. If a sewage treatment works is thought of as an industrial plant and the people who are paying for its construction and operation are considered as stockholders and purchasers of the finished product, the need for good business management and good operating practices is immediately apparent. There is no manufacturing plant in which raw materials can be fed in one end and the finished product taken out of the other end with no employees, no supervisory staff, and no management between the two ends. The same thing is true with sewage treatment works. Raw material comes in at one end; within the plant, work is performed and a finished product is discharged. However, there are certain manual operations which must be done. There is a certain amount of supervision required; a certain amount of checking of the process in its various stages is necessary. The persons doing these things must know what they are doing if the finished product is to represent the best obtainable from the plant. To insure proper supervision, properly educated and experienced personnel is essential. Some of the work can be performed by what is generally termed common labor, but supervision is required. Certification of sewage treatment works operators is a step toward improved supervision at many plants.

In addition, there is the matter of records and reports. In every business there are records of raw materials received, production, finished products shipped, labor costs, and power costs. From these records the management knows if the plant is operating properly and efficiently and the stockholders know whether or not to expect a dividend. Records and reports are an essential part of operation and management.

So too, there must be records and reports of treatment works operation. How else will the city officials and taxpayers know if their plant is doing what it was intended to do, whether the receiving waters are what they were intended to be, whether requests for funds are justified, and whether plant expansions are needed? How else than with records can a court action brought on by some displeased riparian owner be defended? From daily records come monthly reports required by statute to be filed with the State Health Department, and annual reports to support budgetary requests.

Municipal "Step-Child"

Unfortunately, this "manufacturing" plant is always located in the least desirable part of the town—either in the vicinity of the heavy industrial section, in the slum area, or in some remote spot not related with residential areas. For this reason, the plant is seldom seen by the stockholders; it is seldom looked at by the municipal officials and is invariably the first item to feel the effects of an economy drive on the budget. This is a situation to which all must give attention. A few cities have made the sewage treatment works site a public park. The management of the plant has done a marvelous job of salesmanship. Unfortunately, examples of this nature are few and far between. There is no reason why the sewage treatment plant should not be just as much of an asset to the municipality as a beautiful city hall, a civic auditorium, or a new fire station. It was this need that prompted formation in the Michigan Sewage Works and Industrial Wastes Association of a committee on plant operation improvement to see what could be done to promote greater interest, better operation, and greater appreciation of those treatment works already in existence.

Promotional Aspect Important

Occasionally one hears of a community that is well informed about its municipal practices or municipal plans. In one town, for example, the superintendent of the water plant makes it a practice to get himself invited as the speaker at luncheon club meetings at least once a year, and preferably twice a year. At that time he informs the group of the things that have happened since he last made an appearance. He tells what economies have been effected, how the quality of the water has changed, how the costs of treatment have changed—all with the view in mind that when it becomes necessary to ask for more money for plant enlargement or new equipment, the group represented will know why it is needed. In another town, it has been the practice to have the senior class at high school visit the treatment works. At first thought this may sound like a waste of time, but it should be remembered that within two or three years after graduation from high school those students will be marking a ballot "yes" or "no," possibly for money for sewage plant construction. In another town, it is the practice to arrange for civic groups to visit the treatment works to be shown what is being done with the dollars they are spending. The possibilities for selling sewage treatment works have not even been tapped. Although sewage treatment is primarily a technical job of removing solids, B.O.D., bacteria, and other objectionable features from the wastes of a city, the sales promotion aspects should not be overlooked. Even though the superintendent is not a born salesman, there is no excuse for not taking advantage of every opportunity to inform the people of his community as to what the plant is doing. Providing a safe, palatable water supply is accepted as an obligation of every municipality. Removing polluting material and restoring our lakes and streams for bathing, fishing, and other reasonable uses is an equal obligation. The problem is to get the public to recognize that obligation and municipal officials to accept it.

Summary

The keys needed to obtain successful sewage services are:

1. The key of "understanding." The reason for, and purpose of a sewer system and treatment works must be understood. There must be an understanding and appreciation of the real value of water resources—how much they are worth today and how much more value they can have.

2. The key of "sound engineering principles." The sewer system and treatment works must be engineered. The skills taught engineers must be applied in this type of factory.

3. The key of "sound financing." Because this is a long-term investment involving the taxpayers' dollars, it must be reasonably and soundly financed; it must represent a gilt-edge investment.

4. The key to "firm bidding." The days of cost plus, escalator clauses, and fixed fee construction are over. Competitive bidding from well-prepared working plans and specifications is needed. Careful attention to details is now required.

5. The key to "good construction." The best of materials and workmanship must be specified, and then followed by strict attention to the plans and specifications during construction. The object should be getting what is called for in the manner or method called for.

6. The key to "good management and operation." The plant must be operated efficiently and consistently. A full return is expected for the money invested; anything less will not be acceptable to the investors or the public.

Reference

1. "Municipal Sewer Ordinances." Manual of Practice No. 3, Fed. of Sewage Works Assns. (1949).

AIR DIFFUSION WITH SARAN-WRAPPED TUBES*

By James H. Blodgett

Superintendent, Sewage Treatment Plant, Columbus, Ohio

The new Columbus, Ohio, sewage treatment plant went into partial operation in November, 1937, with the activated sludge section, including the aerators, being placed in operation in August, 1938. These aerators, of which there are eight, are of the two-pass conventional Y-wall type tank with 26-ft. width and 15-ft. water depth. Each pass is 370 ft. long; the detention period at 50 m.g.d. with 30 per cent returned sludge is computed to be 6 hr.

The air supply for activation in these tanks is through the medium of four, 3-stage centrifugal blowers, two of which have 21,000-c.f.m. and two 15,000-c.f.m. capacity at 7.3 lb. discharge pressure, with air temperature at 60° F.

The diffusing medium for activation was composed of 12-in. square carborundum plates of 1-in. thickness having a permeability rating of from 40 to 45. These plates, arranged in two rows and with four cross diffusers in each tank bay (see Figure 1), totalled 1,328 per tank. Grouted in place in precast concrete containers, the plates were served by means of an air main located in the trough of the tank division wall, with lateral risers connecting with the diffusing units on the tank bottom.

The air supply is filtered by means of oil immersing screens and dry paper filter packs on the suction side of the blowers.

Diffusion Troubles

The operation of this system was quite satisfactory and efficient for the first five years, but from 1943 on, difficulties developed which required investigation and a search for a solution.

So-called "blows," indicated by areas of concentrated turbulence on the surface of the tank liquid, appeared. These spots increased in number and intensity as time went on. Obviously this condition seriously impeded the proper distribution of air in the tanks and caused practically insurmountable difficulty in operation.

After dewatering the tanks and hosing off the plates, inspection showed that in places the cement grout, in which the plates had been imbedded, had deteriorated, thus allowing the air to escape along the edges of the plates and causing a large volume of air loss with no diffusing effect. It was very difficult to locate each of these failures by visual observation and inspection of the dry plates, but by filling the tanks with water until the plates were submerged a few inches and turning on the air, the defective joints were easily located and the plates marked for attention.

The first attempt at repairs was to carefully dig out the affected plate joints and refill them with "Embeco," an expanding cement mortar. At the same time, all plates were scrubbed with a solution of hydrochloric acid to remove a deposit of lime and magnesium salts accumulated on the surfaces. After allowing sufficient time for the mortar to set, the tank was placed back in operation. This method of maintenance required that a tank be out of service approximately four weeks and after completing four tanks, the work was interrupted by other emergencies

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28-30, 1950.

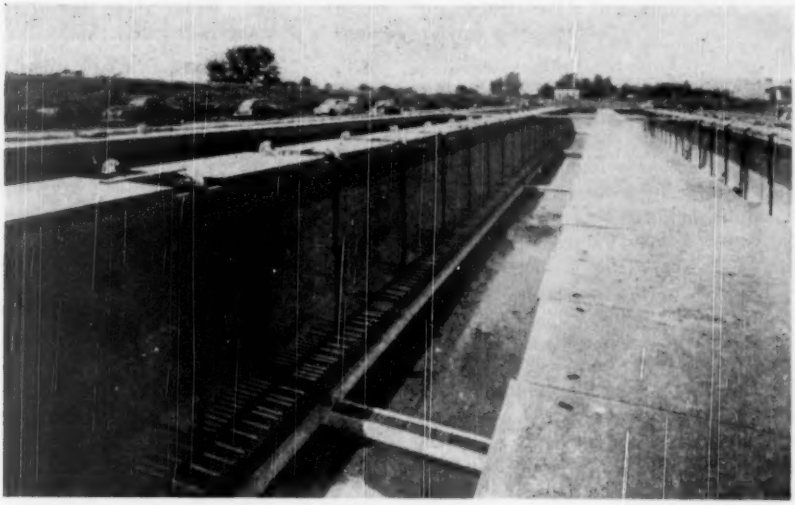


FIGURE 1.—Aeration tank in process of alteration, showing original plate diffusers and new Saran-wrapped tube diffusers.

and nothing was done to the other four until the following year.

In the meantime, it was found that although the work done on the first units eliminated the "blows," the discharge pressure on the blowers was increased. Further investigation showed that in spite of the air being filtered, an accumulation of dirt was evident on the bottom of the plates. This soon became another source of trouble, for with an increase of pressure from 7.3 lb. to 8 or 8.5 lb., not only was more power required, but also, due to the characteristics of the blowers, the large and small units could not be operated in parallel at this pressure.

As a result, the air output was restricted to the capacities of the two large blower units, which at 8 to 8.5 lb. pressure was but 39,000 c.f.m. total, a loss of 7 per cent in efficiency.

Theoretically, under the existing conditions, this amount of air should be sufficient for a flow of 60 m.g.d., but faulty distribution through plate failures in the unrepaired tanks and the recurrence of failures within a few months of unrepaired joints in the reconditioned tanks, made it impossible to handle even the designed capacity of 50 m.g.d. of flow through the units.

Temporary Relief Measures

The condition had to be relieved through some means as quickly as possible, for by 1944 the flow to the plant had increased to between 60 and 65 m.g.d. and it was evident that it could not be handled under such conditions. As a temporary relief, auxiliary connections were made to the air main risers and one row of perforated pipe was installed in each tank.

This work was done in 1945. Some improvement was accomplished, although continuing joint failures badly upset the uniformity and efficiency of the diffusing units in a comparatively short time. In the meantime, it became evident that the over-all plant capacity would have to be increased to handle a continually increasing sewage flow.

Additions and Alterations

Investigation and studies developed the need of certain other facilities, among which additional aerating units were considered. If the existing system of fixed plate diffusers was to be retained, it was evident that an extra unit would be required, to allow for one tank being out of service periodically for plate maintenance and to handle increased flows of sewage.

The cost of the additional unit was estimated at $400,000. From previous experiences, it was estimated that approximately $3,000 per year would have to be spent on plate maintenance. Compared with this cost, the modification of the existing system to one using swing diffuser units was estimated at $300,000, with the maintenance cost no more than that for normal operation and maintenance of the activated sludge section, as the units can be removed, cleaned, or replaced by the operator during spare moments and as part of his regular routine duties, without interrupting or interfering with the operation of the individual tank or the plant as a whole.

Therefore, plans were prepared and bids taken to modify the plate and container system to one using swing diffusers with ceramic tubes. The low bid, after adjustment, amounted to $312,000. This figure resulted after deleting from the contract an item calling for removing the existing plates and containers. The plates were removed by plant forces, the containers being left in place.

The contract was awarded in September, 1947. However, due to material shortages it was not until May, 1948, that work was under way. In the meantime, a request was made to substitute Saran-wrapped tubes for the ceramic tubes specified.

Inasmuch as this type of tube was new on the market, very careful investigations were made of their diffusing qualities, resistance to acid and alkaline solutions, and resistance to bacterial action. From these investigations it was concluded that this type of tube was equal in all respects, and superior in many respects, to the ceramic type tube as specified. Consequently they were accepted for installation.

Work proceeded from May through September, 1948, at which time the contract was completed. Two tanks at a time were taken out of service and equipped with the modified diffusing system (Figure 1). As fast as the conversions were finished the tanks were placed in actual service.

Results with Saran-Wrapped Tubes

Beneficial results were evidenced immediately in lower air pressure on the blowers, more uniform distribution of the diffused air (Figure 2), and the ability to operate the units while maintaining good aerobic conditions at an increased capacity of 20 per cent over the original designed rate of flow through the tanks. For the period of September through the middle of December, 1948, the units were loaded to average rating of 60 m.g.d., against a designed rating of 50 m.g.d., without any trouble. This was accomplished with a serious handicap of having available only one-half of the primary settling tank capacity, as modification work was being carried on simultaneously on these units.

From December 15, 1948, through April 15, 1949, the entire plant had to be shut down while the newly constructed grit collectors were being cut in to the intercepting sewer and the sewer itself cleaned of accumulated grit. In the meantime, to save power costs, the blowers were shut down and the aeration tanks were drained, leaving about 3 ft. of water in the tanks to protect the diffuser tubes from freezing during the winter. Air was blown through the system only once a week to discourage slime formations on the tubes.

When the plant was placed back in operation on April 15, it was immediately noted that the air main pressures had increased about 1.5 lb. over what

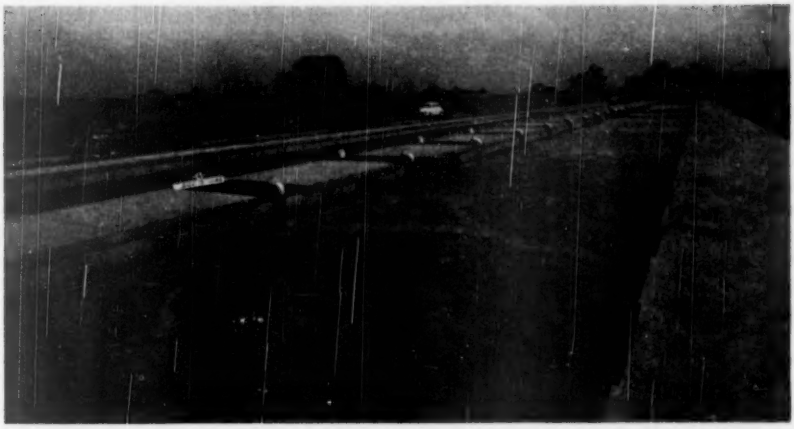


FIGURE 2.—Aeration tank in operation following modified installation, showing uniformity of air distribution.

they were before the plant was shut down. Investigation showed the tubes to be coated with a dun colored, clay-like material, which dried readily when exposed to the air.

It looked like a simple matter of dry brushing the tubes to clean them; this was done. All tubes were raised, dried and brushed in place, alternate units being raised in each tank so that at no time was the tank out of service. The dry brushing reduced the discharge pressures about 0.75 lb., but they started to build up again within a couple of months.

Sand Caused Coating

In the meantime, the source of the coating material was investigated and finally discovered to be right in the tanks themselves. When the diffuser plates were removed, the concrete containers were left in place and, at the suggestion of interested parties, were filled with washed sand, it being thought that possibly organic material would settle in the containers, decompose, and place an extra load on the unit.

Analysis of the coating material showed it to be 90 per cent silica, which gave the clue that the sand, in combination with organic matter, had caused the trouble. When the tanks were drained the sand was found everywhere but in the containers, proving that fears of organics settling there were unfounded. Therefore, all the sand was removed from the tanks.

Removal of Residual Coating

Experiments to determine the best method of removing the ceramic coating not dislodged by brushing, developed into a simple soaking of the tubes for approximately 12 hr. in a 3 per cent solution of sodium silicate plus a non-ionic detergent, after which the tubes were passed through a high-pressure water jet, which completely removed the softened and loosened material from between the cords.

Using the facilities at hand, provisions were made for a tube-cleaning project. All of the tubes in the tanks (some 6,400) were removed in batches of 200, soaked, and cleaned. This operation was not completed until September, 1949, due to the necessity of starting from scratch on a problem unfamiliar to all.

The controlling factor as to the speed

with which the cleaning could be accomplished was found to be in the provisions for soaking. The soaking tank (Figure 3) was built large enough for only 200 tubes, which restricted treatment to only 400 tubes per day. However, a larger tank would permit up to 800 tubes per day to be cleaned in this manner, as the jetting operation takes only the time required to remove the tube from the tank and pass it quickly through the jet—less than 1 min. per tube.

Some tubes were found to be stained with iron compounds. These were immersed in a 10 per cent hydrochloric acid solution for about 30 sec., then passed through the jet again. Only about 10 per cent of the tubes had to be treated thusly.

Out of each batch of 100 tubes cleaned, two tubes were selected at random and tested for loss under 6 cu. ft. per min. air flow. They were required to test within 1 in. of water pressure of that established for a new tube. If they failed to meet this test, the batch from which they were selected was held out, resoaked, and put through the process again. Only two batches failed to meet the test requirements. Among other things, the test gave an indication that the strength of the soaking solution had been depleted and needed renewing.

It was found that three batches, or 600 tubes at the useable capacity, was about all that could economically be gotten out of each batch of soaking solution. However, a system of recirculation of the solution in the tanks has now been installed. This not only cuts the soaking time 25 per cent, but also extends the use of the solution to four batches. Also, an improved type of jet, which flushes the tube inside as well as on the outside, has been constructed. In the tests thus far run the new jet has proven quite satisfactory.

When the tubes were once cleaned as described, the pressure on the distributing system immediately dropped to 6.75 lb. when passing approximately 5 c.f.m. of air per tube, or exactly what it was when the tubes were new and just installed. However, a gradual build-up in pressure occurred over a 6-month period. A sustained increase

FIGURE 3.—Plant-made facilities for cleaning Saran-wrapped tubes, showing soaking tank (left) and high-pressure jetting device.

FIGURE 4.—Unit raised for accessibility, showing method of jetting in place to remove loose coating materials.

of approximately 0.75 lb. has been found to be an indication of tube clogging on the outside. When this limit is reached the units are raised and cleaned of their bacterial jelly coating.

This is done by means of a high-pressure water jet (Figure 4) developed at the plant. The jet, which is in the form of a ring having perforations on the inside face, is connected to a high-pressure water hose and passed over each tube separately, the tube remaining attached to the header pipe. The air pressure is left on the tubes while they are being jetted.

The "jetting in place" has a very beneficial effect on the pressure, reducing it as much as 0.5 lb. From all indications it does not, however, clean the tubes to new tube rating. It is estimated that probably every two or three years, the tubes should be removed from the tanks, soaked in the solution, and jetted to return them to new tube performance. Experience will tell the frequency with which this must be done.

Cost of Cleaning Tubes

Recently connections were installed in the air supply piping at various locations in the aerators and readings are being taken periodically to determine air flow and pressure losses, in order to establish the rate of build-up of pressures and whether the build-up is faster in one part of a tank than another. These data are expected to be useful in establishing a regular schedule of cleaning operations.

From this information also, it is expected to be able to balance the cost of cleaning operations against the increased power costs due to the higher pressure. It will then be known whether to jet in place, or remove, soak, and jet the tubes to original head losses, and how often one or the other should be done.

From the data collected during the first attempts at removing, soaking, and jetting the tubes, it cost 10¢ per tube to clean them to practically new tube performance. To raise the units

and partially clean the tubes by jetting in place cost about 2¢ per tube.

Assuming the tubes must be removed, soaked, jetted, and replaced once every two years, and the units must be raised and cleaned in place twice a year, it will cost $10¢ \div 2 = 5¢$ per tube per year for the biennial removal, soaking, and jetting, plus $2¢ \times 2 = 4¢$ per tube per year for the semi-annual jetting in place. Thus, the total cleaning cost is $5¢ + 4¢ = 9¢$ per tube per year. Cleaning of the plates every four years requires that two of the eight aeration tanks be done each year, involving 2,660 plates at a total cost of $3,000, or $1.12 per plate per year. Furthermore there are only 800 tubes per tank, doing more work than was formerly done by 1,330 plates.

No attempt has been made to apply the fixed charges incurred by reason of the additional cost of the modifications. It is self-evident that it would be more expensive to provide additional aeration units to obtain the same flexibility and capacity afforded by the present installation.

FEDERAL LOANS FOR OHIO VALLEY SEWAGE PLANNING

Interest-free loans from the federal government totalling almost $2,000,000 will advance installation of sewage disposal facilities serving 105 communities in the Ohio Valley. This was announced recently by the Ohio River Valley Water Sanitation Commission, which represents eight states engaged in a joint campaign for the conservation of water resources by pollution control.

The loans, which were approved by the U. S. Housing and Home Finance Agency, are being employed to prepare plans for 47 sewer and treatment plant projects in the eight states. Cost of the completed projects is estimated at $102,000,000. Commission officials state that construction of these projects, which will serve almost 16 per cent of the total population of the valley, will provide a significant reduction in the pollution load now being discharged into Ohio Valley streams.

The breakdown, by states, of projects and loans for communities in the Ohio Valley shows that Illinois has received $26,000 for two projects; Indiana, $445,000 for 17 projects; Kentucky, $76,000 for 5 projects; Ohio, $495,000 for 11 projects; Pennsylvania, $657,000 for 5 projects; Virginia, $6,000 for 1 project; and West Virginia, $181,000 for 6 projects.

The largest single advance was $500,000 to the Allegheny County (Pa.) Sanitary Authority, which is designing an intercepting sewer system and a huge treatment plant. Estimated cost of the project is $59,000,000. The system will treat the wastes from 59 municipalities, including Pittsburgh, and 30 industries.

Youngstown, Ohio, received the second largest advance—$265,000—for an estimated $9,000,000 construction program, including an interceptor sewer system and treatment plant.

STUDY OF THE NITRIFICATION PHASE OF THE B.O.D. TEST *

II. Development of an Incubation Vessel for Multiple Determinations

By A. M. Buswell, Irene Van Meter, and J. R. Gerke

Illinois State Water Survey, Urbana, Ill.

There has been ample evidence in B.O.D. work that reactions occurring in different bottles, supposedly with as nearly duplicate contents as possible, do not necessarily proceed at the same rate. A study involving the quantitative relationships existing between the reactants and products would, therefore, necessitate that samples for the determination of these substances be taken from the same bottle. The dissolved oxygen test, however, requires a full bottle of sample, thus precluding the possibility of making other tests on the same culture when incubated in the B.O.D. bottle.

Three possible solutions to this problem are suggested:

1. Manometric procedure.
2. Transfer of dissolved oxygen sample.
3. Two-compartment incubation vessel.

Manometric Procedure

Probably the first attempt at the use of the manometric or direct oxygen absorption technique for the determination of the oxygen requirements of the biological processes involved in waste treatment was made by Adeney (1) in 1908. Sierp (2) in 1928, followed by Symons and Buswell (3) in 1929, also experimented with this procedure. Burtle and Buswell (4)(5) made a comparison of the permanganate oxygen demand, the dilution B.O.D., and direct absorption as determined by the Nordell Odeeometer. More recently, studies along this line have been conducted by various investigators such as Heukelekian (6), Falk and Rudolfs (7), Caldwell and Langelier (8), and Dawson and Jenkins (9) (10). Their reports indicate that the equipment required is rather costly. The accuracy, in general, is satisfactory for sewage and industrial waste B.O.D. determinations. However, the procedures would require considerable modification and refinement for a study of the precise quantitative relationships involved in nitrification, in which it is necessary not only to determine oxygen uptake, but also to determine nitrogen balance during successive periods of incubation.

Transfer of Dissolved Oxygen Sample

A second method by which dissolved oxygen and additional determinations might be made on the same culture is by the use of Ruchhoft's (11) procedure; namely, incubating in 500-ml. flasks and subsequently transferring the dissolved oxygen sample by siphoning from the flask into a regular B. O. D. bottle. As a transfer introduces the possibility of altering the concentration of dissolved oxygen in the sample, a group of experiments was devised to determine the magnitude of

* This work was carried out under U. S. Public Health Service Research Grant 2141 (formerly 762–C) to the Illinios State Water Survey.

error introduced by transferring at medium and low oxygen concentrations in the presence of air and in the absence of air. Carbon dioxide (obtained from dry ice) was used in the first two experiments, and compressed nitrogen in the last two experiments as the "replacing gas."

Procedure

The sodium azide modification of the Winkler test (12) was used to determine dissolved oxygen in all experiments. Five liters of boiled and cooled water were aerated to the desired oxygen concentration in a reservoir (8-l. bottle). The purpose of the reservoir was to make available a supply of water with constant dissolved oxygen level. In order to prevent further aeration of the water, the air above was replaced by the replacing gas. (The extinguishing of a burning splint was the criterion of replacement of air by the gas in all cases.) While drawing samples from the reservoir, this gas was admitted through the gas inlet (Figure 1).

By slow siphoning to prevent splashing, samples for each experiment were drawn from the reservoir into bottles or flasks filled with the replacing gas. The first three samples were drawn into B.O.D. bottles, the next six into 500-ml. ground-glass-stoppered flasks, and the last two into two more B.O.D. bottles. The purpose of the first three samples drawn into B.O.D. bottles (A) was to determine the dissolved oxygen level in the six 500-ml. flasks. However, analysis of the results of a preliminary experiment indicated that the dissolved oxygen concentration of successively drawn samples decreased by a small but significant amount. This was due to loss of dissolved oxygen to the "replacing gas" in the reservoir. The last two samples in B.O.D. bottles (A′) were taken to determine the extent of decrease in dissolved oxygen throughout the experiment. The six 500-ml. flasks were divided into two groups, the first three drawn and the second three drawn. It was possible to compute the average dissolved oxygen concentration in each of these two groups by straight-line interpolation between the average concentration of the first three B.O.D. bottles (A) and the last two (A′). The computed aver-

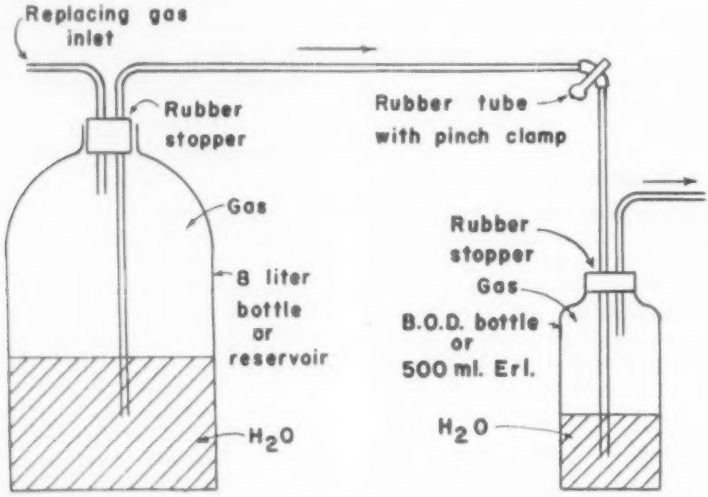


FIGURE 1.—Method of drawing dissolved oxygen sample.

TABLE I.—Interpolation to Determine Dissolved Oxygen (in p.p.m.) in 500-ml. Flasks

Samples	CO_2 Experiments		N_2 Experiments	
	No. 1[1]	No. 2[2]	No. 1[1]	No. 2[2]
A_1	1.50	3.73	1.03	5.40
A_2	1.51	3.81	1.00	5.36
A_3	1.51	3.71	—	5.35
A[3]	1.51	3.75	1.02	5.37
A'_1	1.55	3.58	1.03	5.25
A'_2	1.52	3.60	0.96	5.25
A'_3	1.53	3.59	0.99	5.25
B'[4]	1.51	3.70	1.01	5.33
C'[4]	1.52	3.65	1.00	5.29

[1] Low oxygen concentration.
[2] Intermediate oxygen concentration.
[3] Average.
[4] Interpolated.

age for the first three 500-ml. bottles is termed B′, and for the second group, C′ (See Table I.)

To determine the effect of transferring a dissolved oxygen sample into a bottle filled with the replacing gas, samples from the first three 500-ml. bottles were siphoned into three B.O.D. bottles containing the replacing gas. The average dissolved oxygen concentration for these is designated as B. Since B is less than B′, as shown in Table II, there was a loss in dissolved oxygen due to transferring in the presence of the replacing gas.

To determine the effect of transferring in the presence of air, samples from the second three 500-ml. bottles were siphoned into B.O.D. bottles containing air. The average dissolved oxygen concentration for these is designated as C. Since C is greater than C′, as shown in Table III, there is a gain in dissolved oxygen due to transferring in the presence of air.

TABLE II.—Effect on Dissolved Oxygen (in p.p.m.) by Transferring in Presence of Replacing Gas

Samples	CO_2 Experiments		N_2 Experiments	
	No. 1	No. 2	No. 1	No. 2
B_1	1.51	3.61	0.96	5.23
B_2	1.41	3.55	1.02	5.20
B_3	1.45	3.55	1.00	5.25
B (av.)	1.46	3.57	0.99	5.23
B′–B (av.)[1]	0.05	0.13	0.02	0.10

[1] Loss in D.O.

After examination of these data, the following conclusions were reached:

1. In transferring a sample of water from one flask to another in the presence of air, the gain of oxygen can be significant when errors in the order of a 0.1 p.p.m. cannot be tolerated. This error is inversely proportional to the concentration of dissolved oxygen; however, the amount of gain is variable with the conditions of the individual experiment and is not predictable.

TABLE III.—Effect on Dissolved Oxygen (in p.p.m.) by Transferring in Presence of Air

Samples	CO_2 Experiments		N_2 Experiments	
	No. 1	No. 2	No. 1	No. 2
C_1	1.60	3.68	1.12	5.30
C_2	1.61	3.65	1.12	5.50
C_3	1.61	3.61	1.18	5.30
C (av.)	1.61	3.65	1.14	5.37
C (av.)–C′[1]	0.09	0.00	0.02	0.08

[1] Gain in D.O.

2. In transferring a sample of water from one flask to another in the presence of carbon dioxide or nitrogen, the loss of dissolved oxygen is likewise significant and proportional to the concentration of dissolved oxygen; however, the amount of loss is variable with the conditions of the individual experiment and is not predictable.

3. In this experiment there was no significant difference in the loss of dissolved oxygen between samples handled in atmospheres of carbon dioxide and those in nitrogen.

Two-Compartment Incubation Vessel

As previously pointed out, the dissolved oxygen test requires a full bot-

tle of sample, permitting no samples of this culture for the other determinations, and, as the above experiment demonstrated that an error of uncertain magnitude is introduced by transferring the dissolved oxygen sample, a two-compartment incubation vessel or "double bottle" was devised.

This two-compartment vessel or "double bottle" (Figure 2) consists of a 300-ml. Erlenmeyer flask with a female 19/38 ground-glass joint, into which was inserted the male joint of a 200-ml. bulb with 19/38 joints on both

FIGURE 2.—Two-compartment incubation vessel.

ends (one male and one female). The stopper was fashioned from a 19/38 male joint. A standard B.O.D. bottle, the neck of which has been ground to accommodate a male 19/38 joint, can be substituted for the 300-ml. flask. To sample a culture in such a bottle, the top bulb is removed and held over a beaker, leaving a full bottle of sample for the dissolved oxygen determination and at the same time the contents of the bulb are available for ammonia, nitrite, and nitrate determinations.

In a preliminary series, it was found that when nitrification was incomplete and no attempt had been made to mix the contents of the two compartments, as much as 300 per cent more nitrite might be found in one compartment than in the other.

Mixing presented a problem, in that the bottle could not be opened without changing the dissolved-oxygen concentration. Simple inversion failed, as there was not significant difference in the densities of the solutions. A magnetic stirrer failed as it did not provide a top-to-bottom-to-top motion. If small, clean glass beads (2 mm. with hole) or clean sand are added, they pass from one compartment to the other on inverting the apparatus, and produce complete mixing. For example, when 30 ml. of the small beads were placed in the double bottle (total volume approx. 500 ml.) and $NaNO_2$ solution was added to the top of the bottle, the following was the result:

Complete Inversions of Double Bottle	Difference in NO_2^- Conc. between Top and Bottom (%)
15	5
20	2
30	1

Similar results were obtained with 25 ml. of quartz sand as mixing agent.

Inasmuch as the relative difference in NO_2^- concentrations between top and bottom would be less in actual practice, it was concluded that 30 inversions with the small beads or sand would be satisfactory. As sand was available, 25 ml. of rigorously cleaned sand per bottle and 30 complete inversions were used in the experiments. During incubation, daily inversions were also necessary to insure uniformity throughout the culture.

Prior to opening for sampling, the bottle is inverted to allow the sand to flow to the upper compartment. Then the bottle is returned to as nearly an upright position as possible, still permitting the sand to remain in the upper portion while separating the two

parts. With a little practice it is possible to rapidly carry out this operation without the introduction of air bubbles in the upper layer of the dissolved oxygen sample. One operator adds the reagents to the sample, while the other one removes the stopper from the top section and inserts it into the lower section immediately after the reagents have been added.

Summary

Both in routine and research B.O.D. studies, it is often a decided advantage to be able to make, on the same B.O.D. culture, other determinations in addition to that of dissolved oxygen. Under existing conditions, the manometric or direct oxygen absorption procedure was not feasible for the problem of determining the quantitative relationships involved in nitrification. The use of a large container and transferring the dissolved oxygen sample has been shown to lead to an error of the order of 0.1 p.p.m. dissolved oxygen. Although this is satisfactory for some purposes, the precision is inadequate for determining oxygen and nitrogen balances. A two-compartment incubation vessel which overcomes these objections is described. The construction of the vessel is simple and the method of operation described is easy and rapid and avoids the errors of the other procedures.

References

1a. Adeney, W. E., Fifth Report, Royal Commission on Sewage Disposal, App. VI, p. 96 (1908).

1b. *Ibid.*, p. 438.

2. Sierp, F., "A New Method for Determining Biochemical Oxygen Demand." *Ind. Eng. Chem.*, **20**, 247 (1928).

3. Symons, G. E., and Buswell, A. M., *Ind. Eng. Chem.*, Anal. Ed., **1**, 214 (1929).

4. Burtle, J., and Buswell, A. M., "A Comparison of Permanganate Oxygen Demand, B.O.D., and Direct Absorption of Oxygen." *Sewage Works Jour.*, **7**, 839 (1935).

5. Burtle, J., and Buswell, A. M., "Oxygen Demand Studies." *Sewage Works Jour.*, **9**, 224 (1937).

6. Heukelekian, H., "Use of Direct Method of Oxygen Utilization in Waste Treatment Studies." *Sewage Works Jour.*, **19**, 875 (1947).

7. Falk, L. L., and Rudolfs, W., "Factors Affecting the Direct Oxygen Utilization Method." *Sewage Works Jour.*, **19**, 1000 (1947).

8. Caldwell, D. H., and Langelier, W. F., "Manometric Measurements of the B.O.D. of Sewage." *Sewage Works Jour.*, **20**, 202 (1948).

9. Dawson, P. S. S., and Jenkins, S. H., "Oxygen Requirements of Activated Sludge Determined by Manometric Methods." *Sewage Works Jour.*, **21**, 643 (1949).

10. Dawson, P. S. S., and Jenkins, S. H., "Oxygen Requirements of Activated Sludge Determined by Manometric Methods. II. Chemical Factors Affecting Oxygen Uptake." THIS JOURNAL, **22**, 4, 490 (Apr., 1950).

11. Ruchhoft, C. C., Placak, O. R., and Ettinger, M. B., "Correction of B.O.D. Velocity Constants for Nitrification." *Sewage Works Jour.*, **20**, 832 (1948).

12. "Standard Methods for the Examination of Water and Sewage." 9th Edition, p. 129 (1946).

Industrial Wastes

APPLICATION OF pH MEASUREMENT AND CONTROL TO INDUSTRIAL WASTES*

By W. N. Greer

Technical Staff, Leeds and Northrup Co., Philadelphia, Pa.

The use of pH measurements on industrial wastes resolves itself into two primary considerations: (1) continuous recording of pH, whether of raw or treated waste; and (2) automatic control of neutralization, or some specific treatment. The first, satisfactory continuous pH recording, must be capable of accomplishment if automatic control is to be applied. Two problems are thus presented for consideration; namely, what are the factors affecting continuous pH recording and what are the factors affecting automatic pH control?

pH Recording

The continuous recording of pH presents no problem, except in certain types of solutions or wastes carrying suspended material, which might adhere to the pH responsive elements (glass electrode or reference electrode). Any material which would adhere to the electrodes and prevent the waste solution from coming into direct and intimate contact with the elements would render the equipment inoperative until removed, permitting the waste to again come into direct contact with the electrodes. Such material could be oil, precipitated calcium sulfate, or other suspended material. Under conditions where such material is present, the user is faced with two possibilities: (1) clean the elements on some predetermined schedule; or (2) forego the use of pH recording equipment. Fortunately, not too many wastes are encountered where these factors are a problem. At the same time, they should be appreciated by potential users.

Devices are available for measurements in treating tanks, sewers, etc., both as single- and multiple-point recorders, which can be mounted at any reasonable distance (several hundred feet) from the detectors. Mainte-

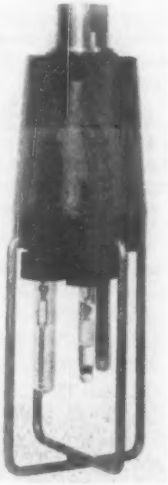


FIGURE 1.—Immersion type electrode unit for pH measurement.

* Presented at 24th Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28–30, 1950.

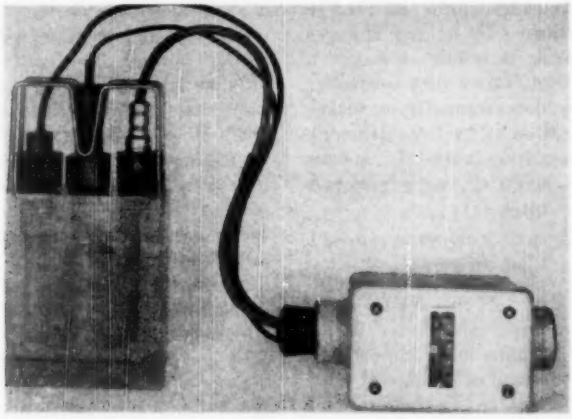


FIGURE 2.—Flow type electrode unit for pH measurement.

nance, exclusive of the cleaning previously noted, is practically nil. An immersion electrode unit, such as might be used in a sewer or directly in a reaction tank or basin, is shown in Figure 1. A flow type, for a continuous test sample supplied by gravity or pumped, is shown in Figure 2.

pH Control

The factors affecting automatic pH control are:

1. Flow rate and rates of change of flow.
2. Acidity and rates of change of acidity of raw waste.
3. Retention and distribution of retention in the treating system.
4. pH control point, or range of allowable pH of treated effluent.
5. Agitation.
6. Rangeability of feeding devices.
7. Detection lag.

These factors are not listed in their order of importance. They are all interrelated; under some conditions one might be very important, whereas under different conditions it might be much less important.

Agitation

The necessity of thorough mixing of reagent with waste, prior to measurement, is too often unappreciated. Certainly, if a true measurement is to be made, a uniformly mixed and reacted sample must be supplied to the electrode assembly. Because automatic control is dependent on the measurement, and further, as will be noted later, a high degree of agitation for all practical purposes eliminates any lag in the treating tank, the importance of good agitation becomes increasingly important.

Flow

As the flow rate, and, therefore, the quantity of material to be treated, is a factor in determining the size of reagent feeding device required, and is also a factor in determining the retention required in the treating system, flow rates are an important factor.

The rates of change of flow, particularly any changes that take place from one minute to the next, or in short periods of time, are a factor because they are an influence in determining the rate at which the treated material could change, or the rate at which reagent feed should be increased or decreased.

It should be noted, however, that reagent feed requirements resulting from flow rate changes are handled by pH

control in the same manner as feed requirements caused by acidity changes. In other words, it is not necessary to control the feed from a flow controller. In fact, flow measurements on wastes give no indication of feed requirements under the condition normally encountered where acidities vary independently of flow rates.

Acidity

It probably is unnecessary to state that the acidity of the waste to be treated is an important factor in pH control. Of perhaps more importance, however, is the rate of change of acidity to be encountered, a factor often given insufficient attention. It is the rate of change of acidity in short intervals—minute to minute—which largely determines the degree of control to be obtained in a given treating system. At high acidities, such as 1 to 10 per cent, a relatively slow rate of change can be as disturbing as a fairly high rate of change at low acidity, such as at pH 3 to 4. It is the actual acidity change per minute which must be considered in laying out the pH control system.

Retention

If it were possible to carry out the neutralization in an infinitely large treating system, no control would be required. The other extreme, where the minimum retention is available and the least desirable control possibilities are presented, is a pipeline system. In between these extremes is an optimum retention for any given waste. The capacity should not be so large that it cannot be adequately agitated. It occasionally develops that it is desirable to split the retention into two or more tanks in series in order to reduce the total retention required, and to provide a control over rates of acidity changes, as will be shown later.

Detection Lag

The detection lag in a system is considered to be the time interval between a change in the reagent feed and the initial recorder response to this changed feed. Because the control responds only to recorder changes, it is necessary that this detection lag be short. On pH control systems this seldom means lags in excess of 1 min.

In most neutralization reactions the rate of reaction of reagent with the waste is essentially instantaneous (an exception to this, which will be referred to later, is that of high magnesia lime). This, when coupled with a high degree of agitation, reduces the detection lag in the normal system to the time required to deliver the reagent from the controlling device to the reaction basin, plus any time required to deliver a treated sample to the electrode assembly. The feeding device and the detecting element can usually be so located that the over-all lag is somewhere between 0.5 and 1.0 min., which are favorable values.

Control Point

A pH control system is one of the few types in which the control point is a factor in the process controllability. This is more or less obvious from a consideration of the relation between acidity and pH as shown in the following:

pH	Acidity
1	0.1
2	0.01
3	0.001
4	0.0001
5	0.00001
6	0.000001
7	0.0000001

Controllability in terms of pH is relatively easy when the control is a low value (such as pH 2 or pH 3) and correspondingly more difficult as the control point approaches pH 7. A given change in acidity results in a much smaller pH change at low pH values than it does at or near pH 7. It is the logarithmic relation between pH and acidity which makes it necessary to consider the value of the con-

trol point when determining the process controllability.

Controllability

The influence of some of these factors can be better appreciated by considering the relations illustrated in Figure 3. Assume an acid waste at a constant flow rate is being treated in an agitated tank as illustrated at the upper right in Figure 3, and that the treated waste is being maintained at some constant value through controlled reagent feed. Also, assume that the acidity of the raw waste instantly changes to some new concentration. The acidity that exists in the tank at any time, t (abscissa), after the influent changes to the new value can be determined if the retention factor, r, of the tank is known (ratio of volume to flow rate). The ordinate in Figure 3 is the percentage retention of the original (controlled) concentration.

It is obvious that at an infinite retention factor there is no change in the acidity in the tank, and that at retention factors less than 1, particularly after 1 min., the concentration in the tank approaches that of the new influent concentration. Knowing the factors involved, it is possible to calculate the deviation from a control value that will occur with a known change in the raw influent. Or, it is possible to calculate the retention required to maintain the deviation within a prescribed limit. If the raw influent acidity changes at some finite rate,

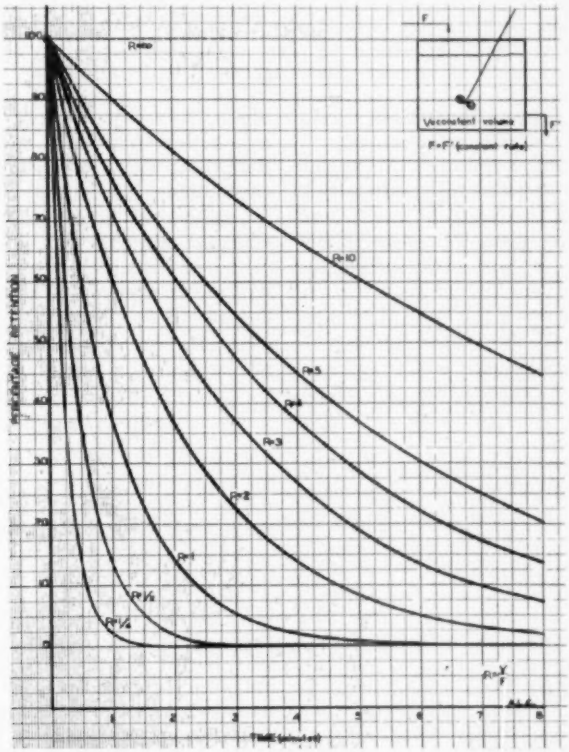


FIGURE 3.—Theoretical control function of retention tank.

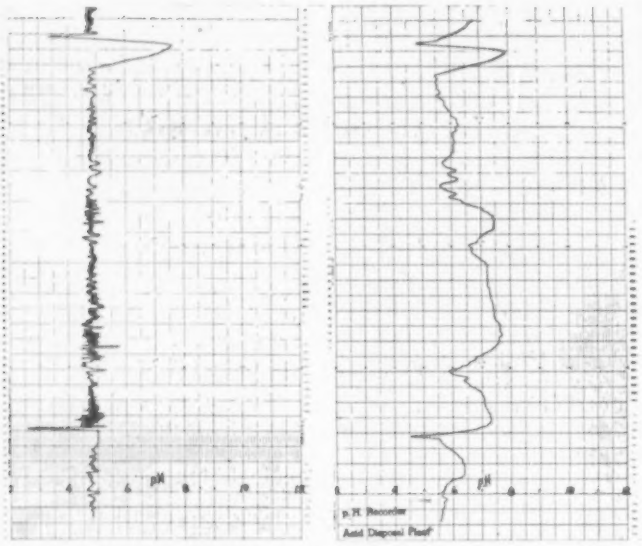


FIGURE 4.—Control at reduced pH (left) to allow for reaction lag in retention tank (right).

rather than instantaneously, it is possible to make similar calculations.

If the required retention is greater than can be satisfactorily agitated, it then becomes necessary to use two or more tanks in series. The value of this arrangement is that each succeeding tank, due to the effect of its retention factor, slows down the rate of change of acidity, and the proper number of tanks of requisite size will produce a waste to the control chamber which can be maintained within the prescribed limits.

Mention has been made of the delayed reaction when using high magnesia lime. In those cases in which the retention factor is less than the time required for completeness of reaction (about 15 min.), it is necessary to carry out the control at a lower pH than the desired final effluent value, and allow for the subsequent pH increase resulting from completion of the reaction. Figure 4 shows the records from such a control. The curve on the left is the controlled pH at a value of 4.8; the curve on the right is the corresponding value in a following retention tank where the reaction reaches completion. The variations in the latter curve are due to the fact that the shift in pH with subsequent reaction increases with higher raw waste acidity and correspondingly higher lime dosage. The raw waste in this specific case varied from zero to about 2 per cent.

Control Equipment

It is not the purpose of this paper to present controlling devices. Suffice it to say that standard equipment is available for controlling the feed of various reagents (caustic, soda ash, lime) either in solution, as a liquid, or dry, by means of electrical or pneumatic operation. This applies not only to pH control of neutralization, but also to oxidation-reduction control such as used in the treatment of chromic acid by means of ferrous sulfate or other suitable reagents.

WASTE DISPOSAL AT A MODERN BREWERY *

By Ruben Schneider

Brewmaster, Lucky Lager Brewing Company, Azusa, Calif.

The Lucky Lager Brewing Company, having been advised by the Los Angeles County Engineer's office that the sewage facilities in the City of Azusa, Calif., were wholly inadequate to meet a brewery's requirements, was confronted with the choice of moving to another building site or developing suitable industrial waste disposal facilities of its own. The company had logically chosen for its 1948 expansion in Southern California a 37-acre tract in the northwest section of Azusa because of the locality's excellent water for brewing purposes, transportation facilities, and sound structural foundation. Consequently, the brewery decided to build its own disposal plant.

The sewage treatment plant of the City of Azusa was originally designed and constructed in 1940 to serve a maximum population of 7,500, or for the treatment of an estimated maximum daily sewage flow of 450,000 gal. The present population of Azusa is approximately 11,000, which in itself indicates that the city is incapable of assuming additional load on an already overburdened sewage treatment plant.

To obtain information relative to the quantities and characteristics of industrial wastes produced by a modern brewery, the Lucky Lager Brewing Company decided to use its San Francisco plant as a guide. For this purpose, the firm of Brown and Caldwell was engaged in a consulting capacity. The information obtained was augmented with additional data and utilized by the Holmes and Narver Company as a design basis for the proposed industrial waste treatment plant. On the basis of this study, it was assumed that for each barrel of beer produced, 13 bbl. of industrial waste water containing approximately 1.5 lb. of B.O.D. and 0.8 lb. of suspended solids would require treatment. Other initial assumptions serving as design values are given in Table I, with comparative actual operation values. The biological filter type of treatment plant was chosen as the most suitable for efficient and economical treatment of brewery wastes, and the high quality effluent, by virtue of its disposal through percolation beds to the underground water basin, was deemed a cooperative measure by the brewery in water reclamation.

Nature of Brewing Process

In the production of beer, an extract of a malt and malt adjunct mixture is boiled in the presence of hops. The resultant "wort" is filtered to remove the spent hops, and then cooled. Brewery yeast is added and the "wort" fermented at controlled low temperatures. The freshly fermented beer is then properly aged, stabilized, filtered several times, and carbonated. The final processing step is packaging in cans and barrels or in bottles cleaned and sterilized in hot caustic solutions.

Segregation of Brewery Wastes

As a means of facilitating the study of brewery wastes, they are segregated into the following groups (see Table II):

* Presented at 1950 Annual Meeting, California Sewage Works Association; Long Beach, Calif.; May 3–6, 1950.

Removed as By-Products

1. Brewers' grains, amounting to approximately 69.9 lb. wet basis or 12.2 lb. dry basis per barrel of beer produced, are extensively utilized as a very desirable constituent of dairy cattle feed. Consequently, they offer no disposal problem.

2. Spent hops, amounting to 2 lb. wet basis or 0.5 lb. dry basis per barrel of beer produced, are presently salvaged and hauled to farm lands for use as an aid in soil reconditioning.

3. Surplus yeast and proteinaceous substances denatured from solutions during fermentation and storage amount to approximately 4.24 lb. wet basis or 0.53 lb. dry basis per barrel of beer produced. All of the proteinaceous material and yeast is completely reclaimed and shipped to a food processing plant specializing in the manufacture of vitamins and meat flavoring extracts from yeast.

Removed by Rubbish Disposal Companies

1. Beer filter cake, consisting mainly of diatomaceous earth and a mixture of proteins, yeast cells, and hop resins, amounts to approximately 1 lb. dry basis per barrel of beer produced. To help minimize the digester load, the filter cake plus washings are removed from brewery premises by tank truck for safe disposal.

2. Precipitated substances accumulated during stabilization of beer are similar to the filter cake washings. They amount to approximately 0.12 lb. dry basis per barrel of beer produced and also are removed by tank truck.

3. Bottle cleaning solutions and wastes from all caustic tanks of the bottle cleaning and sterilizing machines are discharged directly to an isolated caustic solution reclamation system, thereby eliminating the possibility of injuring the biological flora of the waste treatment plant with a load of high pH influent. The caustic reclamation system, in reducing the amount of sodium hydroxide which would otherwise be discharged, is a direct aid in minimizing the sodium equivalent ratio of the effluent. All sludge from the caustic reclamation system is removed by tank truck for safe disposal.

TABLE I.—Characteristics and Flow of Brewery Waste Water

Factor	Initial Assumption	Actual Operation
Beer produced (gal./week)	149,000	187,740
Beer produced (bbl./week)	4,807	6,055
Waste water treated (gal./week)	1,961,500	1,985,000
Waste water treated (gal./gal.beer)	13.2	9.5
Average flow, operating days (g.p.d.)	310,000	335,000
Peak flow, average[1] (g.p.m.)	258	302
Peak flow, max.[2] (g.p.m.)	430	435[3]
Solids, total (p.p.m.)	928	770
Solids, suspended (p.p.m.)	220	200
B.O.D. (p.p.m.)	450	445
B.O.D. load (lb./day)	1,163	1,242
B.O.D. population equivalent[4]	7,756	8,280
B.O.D. population equiv. per bbl. beer	10.2	8.11
Susp. sol. population equivalent[5]	3,792	3,720
Susp. sol. population equiv. per bbl. beer	4.9	3.64

[1] Based on 12 hr. for 60 per cent of flow.
[2] Based on 12 hr. for total flow.
[3] Frequently as high as 600 g.p.m., depending on packaging operations.
[4] Based on 0.15 lb. per capita per day.
[5] Based on 0.15 lb. per capita per day.

TABLE II.—Analysis of Segregated Brewery Wastes

	Amount Segregated (lb./bbl. beer)[1]	Protein[2] (%)	Volatile Solids[3] (%)	5-Day B.O.D. Calc. to 100% Solids (p.p.m.)
Brewers spent grains	12.2	17.5	94.0	133,000
Spent hops and residue	0.5	21.5	99.9	237,000
Filter cake	1.0	17.0	23.3	200,000
Stabilization sediment	0.12	28.0	78.0	1,180,000
Surplus yeast	0.53	58.8	83.5	466,000[4]
Surplus yeast (washed)[5]	—	43.9	80.4	306,000
Surplus yeast (dead)[6]	—	—	83.5	233,000
Beer (filtered)	—	5.8	95.6	1,300,000

[1] Dry basis.
[2] Based on N × 6.25.
[3] Percentage of total solids.
[4] Based on dry yeast, each 35×10^8 yeast cells attributed to 0.466 grams B.O.D. and each pound of yeast attributed to 0.466 lb. B.O.D.; dilutions made from composite samples obtained from fermenting tanks.
[5] Sample concentrated and washed on Buchner funnel to remove all dissolved and soluble solids.
[6] A 1 per cent dilution of initial sample boiled 1 hr.

Disposal of Storm and Uncontaminated Water

All water from roofs and paved areas, as well as cooling water from pasteurizers, is discharged through a storm sewer system into an overflow percolation basin located on the brewery premises.

Disposal of Sanitary Waste

All waste from toilets, wash basins, and other plumbing fixtures is discharged through a sanitary sewer system to the municipal sewer system and sewage treatment plant.

Disposal of Industrial Waste Water

The industrial waste water from the brewery consists mainly of washings from processing tanks and equipment, drainage from spent grains and spent hops, and rinsing water used in the packaging departments. All of the waste water, amounting to approximately 9.5 bbl. per barrel of beer produced, is discharged through a separate sewer system to the industrial waste plant on brewery premises for treatment and disposal.

Treatment Plant Units and Equipment

The industrial waste treatment plant is mainly comprised of the following units (see Figure 1):

1. A piping network adequately designed for transferring specified industrial wastes through the brewery and treatment plant to the final effluent percolation beds.

2. A control house and pumping station containing a raw sewage wet well provided with three 260-g.p.m. centrifugal pumps; a sludge sump equipped with two pumps, each having a variable capacity of 75 g.p.m. when pumping primary sludge; a gas-fired boiler, utilizing the methane gas generated in the sludge digester for subsequent heating of the digester; and a raw influent totalizing flow meter.

3. A rotary self-cleaning fine screen equipped with a screw conveyor for removal of screenings.

4. Two settling tanks (Figure 2). The primary clarifier is provided with a skimmer and sludge raking mechanism. The secondary clarifier, equipped with a bottom raking mechanism, discharges thin sludge to the raw

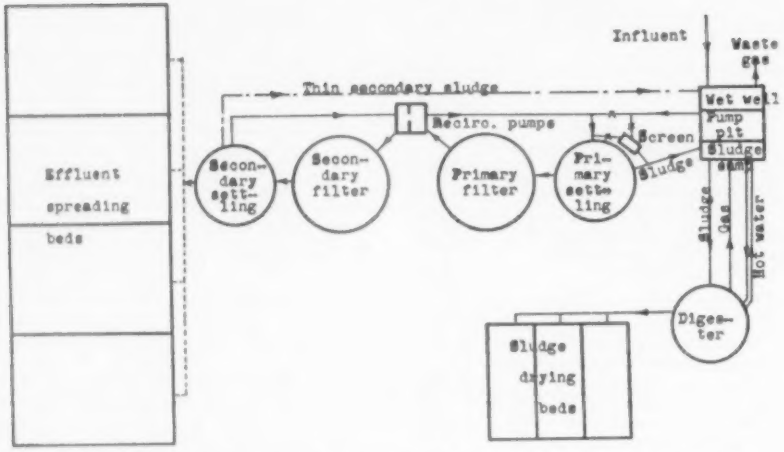


FIGURE 1.—Flow diagram of brewery waste disposal plant at Azusa, Calif.

sewage wet well for complete recycling. Clarifier capacities were based on 2.5 hr. displacement time and are each 40 ft. in diameter by 10 ft. deep.

5. Two bio-filter beds, each 60 ft. in diameter by 3 ft. deep, filled with 315 cu. yd. of granite gravel graded from 2.5 to 4 in. in size and equipped with four-arm revolving distributors. Bio-filter capacities were based on 1.66-lb. B.O.D. removal per cubic yard of stone.

6. A recirculating station (Figure 3) equipped with one 387-g.p.m. centrifugal pump recirculating a portion of the primary filter effluent back to the primary clarifier and one 648-g.p.m. centrifugal pump recirculating a portion of the secondary clarifier effluent back to the secondary filter. Capacities of the pumps are based on a circulation ratio of 2.5 times for both primary and secondary bio-filter units.

7. One sludge digestion tank (Figure 4), 35 ft. in diameter by 20 ft. deep, equipped with a circulating mixer assembly and heat exchangers. Initial calculations were based on 4.0 cu. ft. of digester space required per suspended solids daily population equivalent. The assumed daily equivalent of 3,792 seemed abnormally low for a brewery; therefore, in conform-

FIGURE 2.—General view of brewery waste disposal plant, with effluent spreading beds in background and sludge drying beds at extreme left.

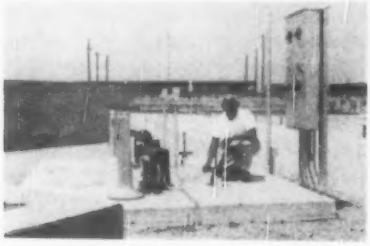


FIGURE 3.—Outdoor recirculation station showing weatherproof motors and controls mounted above ground level.

FIGURE 4.—Prestressed, heated, fixed cover digestion tank with circulating mixer assembly.

ity with suggestions by the State Department of Public Health, the sludge digester was designed for a capacity of 20,000 cu. ft. instead of 15,168 cu. ft. as originally contemplated.

8. Three sludge drying beds, each 30 by 80 ft. The total surface area of 6,400 sq. ft. was based on 1.5 sq. ft. per population equivalent. Each bed bottom consists of a 6-in. layer of sand over a 2-in. pea gravel layer.

9. Four final effluent percolation beds with a total surface area of 32,000 sq. ft. Each bed bottom consists of a 4-in. sand layer over a 2-in. pea gravel layer.

Operational Personnel

The waste treatment plant is operated in conjunction with the rest of the brewery facilities. All of the operating and maintenance personnel are regular brewery employees. Direct operational services are confined to a supervising operator, one full-time laborer, and one part-time chemist.

Plant Operation

Raw untreated liquid waste from the brewery is automatically pumped from the receiving wet well to the primary settling tank, where it is retained for a sufficient length of time for proper sedimentation of sludge and removal of floating scum. The accumulated sludge, removed to a collection hopper by means of bottom spiral scraper blades, is withdrawn at frequent intervals and pumped to the sludge digestion tank. Both scraper and skimmer are in constant operation.

The effluent from the primary settling tank then flows by gravity to the primary filter, and then into a recirculating pump pit. The aerobic biological activity occurring during the passage of clarifier effluent over the cultured stone results mainly in the oxidation and flocculation of soluble organic matter.

The primary recirculating pump returns a portion of the primary filter effluent back to the primary clarifier. The effluent displaced by incoming raw waste flows over a weir and is pumped by the secondary recirculating pump to the secondary filter, which in turn empties into the secondary clarifier. In a similar manner, a portion of secondary clarifier effluent returns to the recirculation pump and the portion displaced by incoming primary effluent flows to the final effluent percolation beds. Both recirculation pumps are in continuous operation and their capacities are based on a 2.5-time circulation ratio. The thin sludge accumulating on the bottom of the secondary clarifier is automatically withdrawn and returned to the raw sewage wet well for reprocessing.

The primary sludge is anaerobically digested, the digested sludge being dried on sand beds. The gas produced is used as a fuel in a hot-water heater located in the control house. The resultant hot water is circulated through coils inside the digestion tank to heat the sludge and consequently accelerate bacterial action. Dried sludge is utilized on brewery premises as a fertilizer.

The fine screening device (ahead of the primary clarifier) was specified mainly as a barrier against spent grains and hops, which may escape control at the brewery and find their way to the treatment plant. This precautionary measure was taken in view of the high B.O.D. content of spent

grains and hops and because operational experience of other waste disposal plants indicated that they become septic rapidly, do not settle readily in the primary tank, and may result in eventual clogging of the filter bed. However, operational vigilance in the brewing departments has alleviated the necessity of the screening device, which is by-passed at the present time.

The skimming device of the primary clarifier was found to be directly responsible for excessive dilution of primary sludge. A minor adjustment of the skimmer eliminated this defect, thereby decreasing the amount of supernatant liquid returned by the digester.

A relatively poor B.O.D. percentage reduction was evident for a short period of time. There was also a strong odor of decomposing organic matter, which was traceable to the filters and sludge receiving pits. It was observed that suspended solids of brewery wastes produced a sludge of light fluid character, which the bottom raking mechanism of the primary clarifier could not easily convey toward the tank's outlet. The thin sludge accumulating in the primary clarifier would become septic and tend to upset the biological balance of the disposal plant, which in turn accentuated the development of odors and decreased the efficiency of B.O.D. reduction. By increasing the frequency of sludge removal from the primary tank, these disturbing abnormal operating conditions subsided.

Weighted samples, based on flow rates, were obtained from both influent and effluent for normal 24-hr. operating periods, composited, and analyzed in accordance with standard procedure. In all instances, averages so obtained gave very similar results. The mean average analysis of the waste water is given in Table III. (In connection with the B.O.D. values given, it should be noted that peak flows higher than anticipated have created a by-passing condition at the secondary filter. Experiments indicate that eliminating this condition, by either diminishing peak flows or increasing the secondary recirculation pump capacity, would result in better than 90 per cent B.O.D. reduction.)

As an additional assurance against the possibility of becoming a public nuisance, the entire waste disposal area was landscaped with trees and foliage specified, first of all to provide a barrier against prevailing windflow, and secondly to sweeten the surrounding air. As a psychological value in assuring the community of the purity of our final effluent, it is used exclusively in irrigation of the plant grounds, and a shelter has been established in the percolation pond area for ducks and swans.

TABLE III.—Typical Analysis of Treatment Efficiency

	Influent	Effluent	Reduction (%)
5- day B.O.D. (p.p.m.)	445	65	88
Total solids (p.p.m.)	770	379	51
Suspended solids (p.p.m.)	200	25	88
Dissolved solids (p.p.m.)	570	354	38
Volatile of total solids (%)	67.5	44.7	67.5
Volatile of susp. solids (%)	73.0	94.0	84.0
pH	7.4	7.6	—
Dissolved oxygen (p.p.m.)	1.0	3.3	—

The disposal plant has been in operation for a relatively short time and operating experience is as yet limited. However, an extensive fact-finding research program, based mainly on the betterment of operating and treatment efficiency, is under way.

Conclusions

The Lucky Lager Brewing Company, when confronted with the necessity of providing a means of disposing of industrial waste from its proposed brewery in Azusa, worked in close conjunction with state and local health authorities for a mutual solution of the problem. The brewery accepted full responsibility for proper treatment and disposal of the industrial wastes involved and, in addition, provided for the reclamation of a large amount of water by returning a high-grade

effluent to the county's underground basin.

From the efficiency of the treatment method, as indicated by a high percentage reduction in B.O.D. and suspended solids, it may be concluded that brewery industrial wastes can be successfully processed by biological methods.

Acknowledgments

The Lucky Lager Brewing Company wishes to acknowledge the assistance and operating suggestions rendered by the Dorr Company; also, to express appreciation to the many city, county, and state officials who were mutually interested in the achievement of a common goal—that of returning purified water to the county's underground water reservoir.

The author also acknowledges the assistance of V. Tapogna, S. Potzmann, and R. Leets; the critical laboratory work of W. Scheffer and L. Roetter; and the valuable criticisms and suggestions of H. R. Henius.

WASTES SAMPLER CROSS CONNECTION

Description of an automatic wastes sampler in the August, 1950, issue of THIS JOURNAL (p. 1047) has brought a comment from an alert reader that a water hose connection shown in the schematic diagram (Figure 1) "incorporates a direct interconnection with a possibly potable water supply."

Although the text does not specifically say so, the water hose connection is provided for backflushing the sampling pipe, as well as for priming the pump after it has been out of service. The pipe to which it is connected is actually a pump suction line, so that under any ordinary usage there would not be any positive backpressure at the hose connection. At the same time, backsiphonage from the waste sewer line possibly could occur through the hose connection under unusual conditions.

In commenting on the matter, the authors of the original paper amplify the description as follows:

"We are familiar with the hazards of cross connections between potable and other water lines and eliminate them in all our installations. The hose in the installations described is connected only long enough to prime the pump after it has been out of service. Moreover, only unfiltered river water is used for this purpose. The hose connection is not essential to operation of the units and should not be included in the general application of the sampler if a potable water supply is involved."

TREATMENT OF PHENOLIC PLASTICS WASTES*

By Norbert H. Kirchgessner

Chemical Engineer, Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

Durez Plastics & Chemicals, Inc., has its plant and main offices located in North Tonawanda, N. Y. The plant occupies a 40-acre site, slightly more than half of which is now occupied by manufacturing facilities. At this location the company manufactures phenolic molding compounds, industrial resins, and protective coating resins, as well as their basic raw materials, phenol and formaldehyde.

Today, Durez represents a typical medium-sized chemical company, which has grown from its small beginning in 1921 to an organization with sales of about $12,000,000 in 1947, the last year for which published figures are available. The Company's growth and waste disposal problems can be divided into several stages.

From 1921 until 1939 it was a relatively small business whose primary interest was the manufacture of phenolic molding compounds. During this period the company was wholly dependent on outside sources for basic raw materials. In 1939 the company acquired the American rights to the Raschig process (1) for the production of phenol and Dr. Walter H. Prahl, co-inventor of the process, came to this country to supervise the construction and start-up of this plant. When the World War II ended, the company, faced once more with raw material problems, decided to manufacture the other basic raw material. Chemical Construction Corp. was engaged to design and erect a formalin plant at the North Tonawanda location. The plant was placed in operation about the middle of 1948 (2).

Sources of Water

The company obtains water from two sources. Water from the North Tonawanda municipal supply is used for process water, sanitary facilities, cooling tower make-up, and boiler feed. Total consumption at the plant for these purposes averages about 0.5 m.g.d. As this supply comes from the Niagara River, the temperature is limited by the high summer temperatures existing in the river.

Well water is used where lower temperatures are required. The water is delivered from wells on the company's property at 50° F. This temperature remains practically constant in summer and winter. At present, about 1,800 g.p.m. are drawn from this source. This water is high in chlorides, sulfates, and sulfides. As a result, it is not an entirely satisfactory coolant. Total water usage from the two sources is approximately 3 m.g.d. per day.

Sewer System

Process wastes and cooling water are discharged to the plant storm sewer system; sanitary wastes are discharged to a separate system. These sewers join the North Tonawanda combined sewer system at the edge of the plant property. The municipal sewers discharge to the Niagara River without treatment, a problem that will be corrected by the proposed North Tonawanda sewage treatment plant.

At the moment, the International Joint Commission, the New York State Water Pollution Control Board, and

* Presented at 1950 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Jamestown, N. Y.; June 12–13, 1950.

the North Tonawanda Department of Public Works are all interested in the company's waste problems.

History of Waste Disposal

Until the phenol plant was completed the waste problem had been in proportion to the size of the business and was, as a result, quite small. No figures are available, but it is probable that before 1939 the total phenol discharged to the sewer was less than 1,000 lb. per day. With the completion of the phenol plant and the start of World War II, a period of expansion and transition started. Within the limitations caused by the war, the waste program expanded at a pace equal to the expansion in production. After the war ended, a new program was started to complete the cleanup job, and this program is continuing.

At Durez, the use of the term "waste in the phenolics plastics industry" generally means phenol. B.O.D. is relatively low, and suspended solids are negligible.

Phenol Plant

When the various phenol processes were being considered the questions of by-products and waste disposal were among the most important considerations. The Durez-Raschig process satisfied the requirements of minimum by-products and minimum process wastes.

The process takes place in two steps:

$$C_6H_6 + HCl + \tfrac{1}{2}\,O_2 \xrightarrow{\text{catalyst}} C_6H_5Cl + H_2O$$

and

$$C_6H_5Cl + H_2O \xrightarrow{\text{catalyst}} C_6H_5OH + HCl$$

The principal wastes from the process are polychlorinated benzenes, hydrochloric acid, caustic wash solution, and tar. The polychlorinated benzenes are recovered in the distillation procedure following the first step and are disposed of as crude dichlorobenzene.

A portion of the recovered hydrochloric acid must be drained from the system in order to prevent build-up of solids and scale deposits in the acid evaporators. This acid, amounting to approximately 2,000 lb. per day, is drained to a wooden tank, where it is completely neutralized by lime and then discharged to the sewer. The discharge contains about 0.2 per cent phenol, and in an effort to reduce the contamination from this source, a continuous filtration and evaporation system is being investigated. This will reduce to zero the phenol discharge from this source.

Caustic washes are used throughout the plant wherever it is necessary to free the process materials of traces of acid. These washes are currently discharged to the sewer. Some are continuous, some periodic. The periodic discharges are released at controlled rates so as not to cause slug-type pollution. It is planned to collect these discharges and send them to the phenol recovery plant as soon as a pH treatment system has been added to this unit.

Table I shows the phenol discharged from the two phenol plant sewers at the time of the International Joint Commission survey. Conditions similar to those in sewer No. 1 on Jan. 18 have been corrected by more frequent sewer sampling in order to discover this type of condition sooner. The condition in sewer No. 5 on Jan. 18 has been eliminated by repiping the

TABLE I.—Phenol Discharged from Plant Sewers[1]

Date	Phenol Discharge (p.p.m.)	
	Sewer No. 1	Sewer No. 5
Jan. 17, 1949	1.3	7
Jan. 18, 1949	125.0[2]	25[3]
Jan. 19, 1949	2.2	5
Jan. 20, 1949	1.7	7
Jan. 21, 1949	9.0	120[4]

[1] Data from I. J. C. survey.
[2] Due to a process leak.
[3] Due to a starting-up condition on a small still.
[4] Due to dumping of a caustic wash solution.

still in order to return the material to the system. Such large phenol discharges as that in sewer No. 5 on Jan. 21 have been reduced by discharging the waste over a longer period of time.

In connection with the caustic washes, one piece of equipment is of particular interest because it embodies a relatively recent development. Water containing traces of phenol, acid, and benzene is neutralized in a vigorously agitated mixer. This mixture was formerly sent to a gravity separator. However, as a result of the mixing, an emulsion was formed and this carried up to 800 lb. of phenol to the sewer each day. Centrifuges were investigated, as well as other specialized separating equipment. At the time this problem was being considered, a paper (3) was published which discussed the breaking of emulsions by means of a glass fiber bed. A small pilot unit was set up and after some minor difficulties had been ironed out, a full-scale unit was installed. The unit operated satisfactorily for 4 months before it became necessary to replace the glass bed. The net loss from this position has been reduced to approximately 10 lb. per day.

In the final purification of the phenol, water seals are used on the vacuum pumps. The seal water, discharged directly to the sewer system, adds a load of about 50 lb. per day. This system is being revamped to allow recirculation of the water. The concentration will be allowed to build up to such a point that it can be handled in the recovery system.

The tars are disposed of by burying on dump sections of the plant property.

Recently, an educational campaign was started among process operators and foremen in an effort to point out the importance of reducing the number of spills and accidental, but continuous, waste. The results are shown in Figure 1. The phenol concentration is not an absolute value, but simply proportional to the phenol content in the plant sewers, averaged over a week's time. This improved condition has been maintained throughout the early weeks of the second quarter.

Formaldehyde Plant

The formaldehyde plant is almost ideal from a waste disposal standpoint. This plant oxidizes methanol to

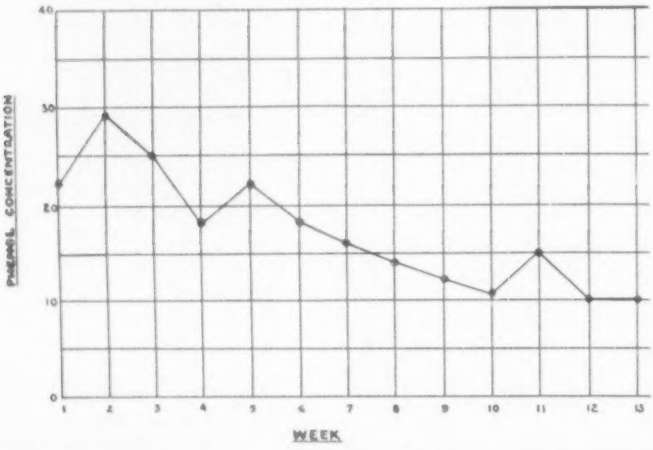


FIGURE 1.—Phenol concentration changes attributed to educational program.

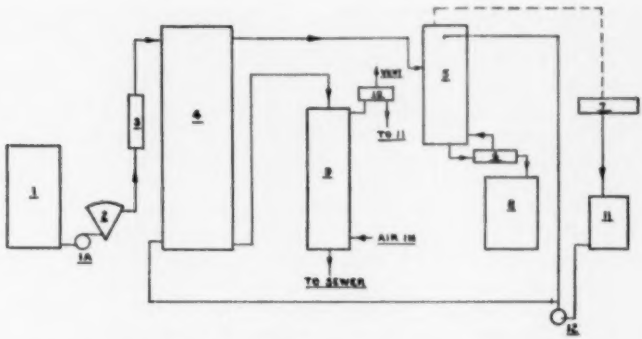


FIGURE 2.—Flow diagram of phenol recovery system showing:

1. Storage (preliminary settling) tank.
1A. Feed pump (10 g.p.m.).
2. Cone filter.
3. Preheater.
4. Extraction column.
5. Fractionation column.
6. Reboiler.
7. Tubular condenser.
8. Phenol storage tank.
9. Benzene recovery column.
10. Helical condenser.
11. Benzene storage tank.
12. Benzene and reflux pump.

formaldehyde in a closed system. There are no process wastes. The only discharge from this plant is a small quantity of spent caustic used in the air washing tower.

Plastics Plant—Industrial Resins

In the manufacture of certain industrial resins, a distillate is produced which contains a high percentage of phenol. When this portion of the company's business began to expand during the early 1940's, it was decided that some action had to be taken. Accordingly, arrangements were completed through the WPB to permit construction of a batch still to handle this material. The still was completed in 1942, and since that time these wastes have been accumulated in a collecting tank and periodically run through the still. The operation of this still keeps several thousand pounds per day of phenol and tar out of the sewer system.

Plastics Plant—Molding Compound Resins

In the manufacture of molding compound resins there is a distillate produced during the dehydration stage which contains (depending on the resin being produced) 2 to 8 per cent phenol. This material was formerly discharged to the sewer at the rate of approximately 60,000 lb. per day. At the end of the war a program was set up to investigate methods of recovering this material. After considerable work, it was decided to install a plant to remove about 90 per cent of the phenol from this waste. The process used was originally developed in Germany by Raschig for protection of the Emscher River, a tributary of the Ruhr. The details for the Durez unit were worked out by Dr. Walter H. Prahl.

A simplified flow sheet of the plant is shown in Figure 2. The distillate from various resin making kettles is collected in a 30,000-gal. storage tank (1), which also serves as a preliminary settling tank. The settlings are largely resinous and are periodically drained off and processed separately.

A pump (1A) is used to feed the distillate at the rate of 10 g.p.m. through the cone filter (2) and pre-

heater (3) to the top of the extraction column (4). The cone filter removes suspended solids and resinous matter. The feed preheater is used to raise the temperature as high as possible, in order to take advantage of the better distribution coefficient of phenol between benzene and water. The limitation is that of the azeotrope of benzene and water at 69° C. In ordinary operation the water temperature is held between 65° and 67° C. Pump (12) feeds benzene to the bottom of the extraction column and also provides reflux to the fractionation column (5).

The extraction column (4) is 3 ft. in diameter and 35 ft. high. It is packed with 25 ft. of 1-in. Raschig rings. The tower was originally packed with ⅝-in. Raschig rings, but these rings became fouled in a very short time. After the rings had been replaced it was found that, contrary to all expectations, the 1-in. rings were giving better separation than had previously been obtained with the ⅝-in. rings. This can only be explained by rapid plugging and subsequent channeling in the ⅝-in. rings, with a corresponding reduction in efficiency.

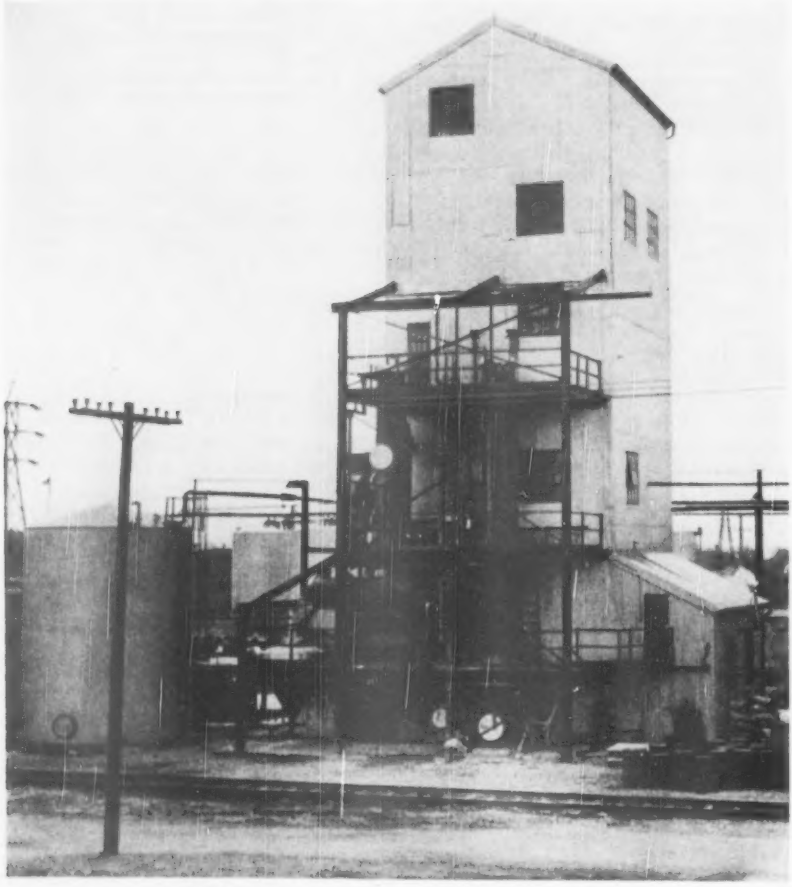


FIGURE 3.—General view of phenol recovery unit.

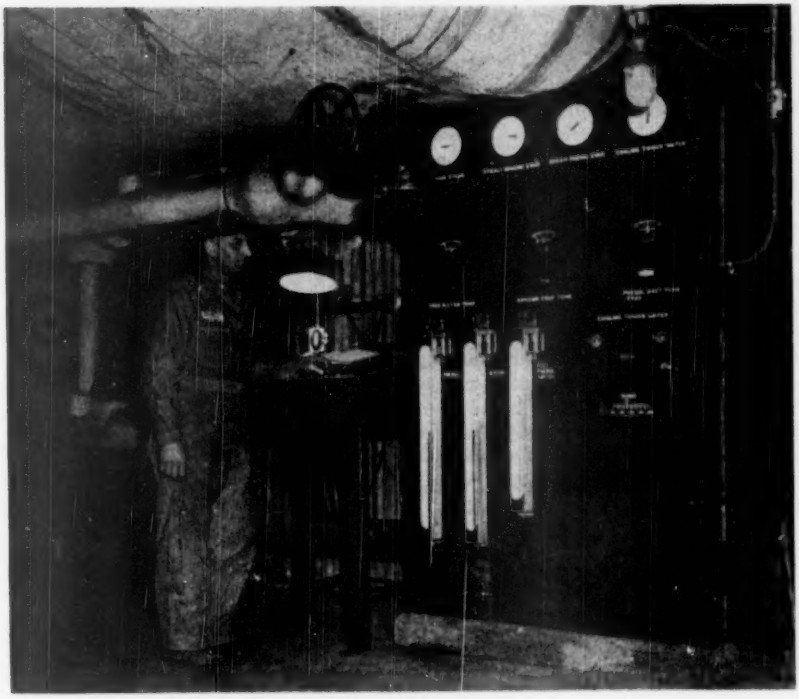


FIGURE 4.—Control panel for phenol recovery unit.

The preheated distillate enters at the top of the extraction column and leaves at the bottom, essentially free of phenol. Depending on the condition of the equipment and the feed temperature, removal efficiency varies from 90 to 99 per cent. The water, saturated with benzene, passes through the benzene recovery column (9), where air is blown through it. Water and benzene are condensed from the mixture of air, water, and benzene in a helical condenser (10). The mixture flows by gravity to the benzene storage tank (11). The water settles to the bottom and is periodically drained.

The benzene-phenol mixture overflows at the top of the extraction column and is fed continuously to a fractionation column (5). The benzene is distilled off and is condensed in a tubular condenser (7) and returned to storage. The phenol is removed as bottoms product from the reboiler (6)

TABLE II.—Average Analysis of Waste Discharged from Phenol Recovery Unit[1]

Flow (g.p.m.)	Phenol (p.p.m.)	B.O.D., 5-Day (p.p.m.)	Chlorine Demand (p.p.m.)	Total Solids (p.p.m.)		Suspended Solids (p.p.m.)		pH
				Total	Volatile	Total	Volatile	
16.4	1,590	11,500	68	506	246	37	21	6.4

[1] Data from I. J. C. survey.

and sent to phenol storage (8). This phenol has a freezing point which normally exceeds 39° C. The impurities are very small quantities of tar and resin residues.

The general layout of the recovery unit is shown in Figure 3; control panel of the unit, in Figure 4.

In the company's long-range waste reduction program the water going to the sewer from the phenol recovery unit is the largest problem. An average analysis of the discharge from this point (Table II) shows that the total B.O.D. at this point is approximately equal to that of the remainder of the plant. With some further changes in process waste discharges and piping in other sections of the plant, it is hoped to have 90 per cent of the B.O.D. and phenol concentrated at this point.

Summary

Since 1942 the Durez company has spent approximately $150,000 to reduce the pollution load on the municipal sewer system. Based on current rates of operation there would be about 7,000 lb. of phenol per day discharged to the sewer if the various steps mentioned above had not been taken.

In cooperation with the various agencies interested in waste problems, a detailed survey of all the discharge lines was recently completed. As a result of this survey, plans are being made for recirculation, repiping, separation of process wastes, etc. After all this work is completed there will still be some wastes with very low phenol concentration (about 1 p.p.m.), for which at present there is no satisfactory method of treating. It is hoped that one of the newer treatment methods will enable completion of the clean-up job.

Acknowledgment

The author desires to express his appreciation to Dr. Walter H. Prahl, Director of Research and Development, and to Durez Plastics & Chemicals, Inc., for permission to publish material contained in this paper.

References

1. Olive, T. R., "Phenol Made by Vapor Phase Regenerative Process." *Chem. and Met.*, **47**, 770 (1940).
2. Olive, T. R., "Durez Synthesizes Formaldehyde." *Chem. Eng.*, **56**, 2, 130 (Feb., 1949).
3. Hayes, J. G., Hays, L. A., and Wood, H. S., "Commercial Desalting Unit Employing Fiberglass as Contacting Agent." *Chem. Eng. Prog.*, **45**, 235 (1949).

BIOLOGICAL OXIDATION OF FORMALDEHYDE*

By Isaiah Gellman and H. Heukelekian

Occurrence of Formaldehyde Wastes

Formaldehyde is used in a variety of industrial processes and, therefore, found in wastes discharged by many industries. Among these are the synthetic plastics and resins industry, producing phenol-formaldehyde and urea-formaldehyde plastics and resins. Dickerson (1) reports formaldehyde concentrations in the liquid waste of such an industry up to 5,000 p.p.m. and contributing 90 per cent of the B.O.D. load in the plant wastes. High-rate trickling filter treatment has proved successful in treating this waste. By using a 40:1 recirculation ratio and a 200-p.p.m. formaldehyde concentration in the waste to the filter, an over-all filter efficiency of 92 per cent has been obtained. Lagooning of the filter effluent increases the over-all efficiency to 99 per cent.

In the tanning industry, formaldehyde is used as a tanning agent, particularly in the production of white suede leather (2). Formaldehyde concentration in the tanning liquor before use is about 3 per cent and the discharged tanning liquor will contain the formaldehyde that has not reacted with the proteinaceous material present in the bated stock.

In the production of anti-biotics, such as penicillin, formaldehyde is used to sterilize the fermentation vats, and to "hold" the media for prevention of bacterial growth. Gilcreas (3) has reported that a formaldehyde concentration of 100 p.p.m., when added to a sludge digester, halted the digestion process, and that the sludge digestion difficulties encountered at one sewage treatment plant were due to the formaldehyde present in the wastes from a penicillin plant connected to the municipal sewer system.

Scope of Investigation

Because formaldehyde is known for its toxic effects on microorganisms and is found in various industrial wastes, studies were conducted to determine:

1. The effect of formaldehyde addition on the biochemical oxidation of domestic sewage.
2. Whether an adapted flora could be developed capable of high-rate oxidation of high concentrations of formaldehyde.
3. The effect of various factors on the activity of such a developed flora.

Previous work had indicated that the toxicity of various organic compounds at definite concentrations in sewage may be overcome by the development of a flora capable of oxidizing the toxic compound at these concentrations. This is accomplished by a process of selection and adaptation whereby the numbers and tolerance of the organisms originally present in sewage are increased by successive transfers.

Methods and Materials

The Warburg "direct method" apparatus was used to measure oxygen utilization rates, which served as an index of the activity of the flora developed in the adaptation process. It had previously demonstrated its usefulness in studying the inhibitory ef-

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J. Presented at American Chemical Society meeting; Detroit, Mich.; April, 1950.

fects produced by the addition of various concentrations of toxic materials on the oxidation of sewage. The direct method has the advantage of allowing such studies to be made over a wide concentration range which is not limited, as in the standard dilution method, by the solubility of oxygen in water (4).

The use of the Warburg apparatus in sanitary research has been described by Caldwell and Langelier (5). The method employed consists of placing a sample under an air atmosphere in a closed system with constant agitation and temperature. The oxygen utilization is measured at any time interval by calculating the decrease in gas volume from change in pressure while maintaining constant volume. All experiments were conducted at 20° C., with measurements made at varying time intervals depending on the degree of adaptation of the flora developed.

A synthetic formaldehyde waste was prepared using chemically pure formaldehyde (approximately 37 per cent), NH_4Cl as the source of nitrogen, and KH_2PO_4 buffer solution for pH control and source of phosphorus.

Samples were prepared containing given concentrations of formaldehyde and seed material. Material from the previous experiment was used as seed for the following experiment. An aliquot portion of the sample was placed in the Warburg apparatus for oxygen utilization rate measurement, and the remainder agitated continuously in a 500-ml. Erlenmeyer flask at 20°C. The latter sample was used for pH measurements, and for B.O.D. determination when desired.

Results

Toxicity of Formaldehyde in Sewage

Formaldehyde was added to domestic sewage in several concentrations from 45 to 175 p.p.m. Increased concentrations resulted in increased lag periods (Table I) before oxidation of the added formaldehyde began. For instance, at a concentration of 45 p.p.m. there was a 2-day lag period before oxygen utilization exceeded that of the control; at 130 p.p.m. the lag period was 3 days. At 175 p.p.m. there was no oxygen utilization at any time during the 7-day incubation period, indicating that neither the added formaldehyde nor the sewage was oxidized. The toxic concentration lies, therefore, between 135 and 175 p.p.m. It is evident that formaldehyde-oxidizing organisms are present in sewage, although in small numbers and with a low tolerance for formaldehyde.

TABLE I.—Effect of Formaldehyde Concentration in Sewage on Oxidation[1] of Formaldehyde

Days	Formaldehyde Concentration (p.p.m.)			
	45	90	130	175
1	0	0	0	0
2	15	0	0	0
3	21	72	43	0
3.25	23	81	92	0
4	25	89	112	0
7	28	90	135	0

[1] In p.p.m. of O_2 utilized.

Development of Adapted Seed

The effects of repeated transfers on the rate of oxidation at increased concentrations are of interest. Starting at 130 p.p.m. formaldehyde with zero per cent being oxidized the first day, the rate of oxidation rose steadily until a value of 95 per cent oxidation was obtained at 445 p.p.m. to 1,750 p.p.m. after 24-hr. aeration. Thus, after several transfers, even a higher concentration, which had been initially toxic to the oxidation of both domestic sewage and the added formaldehyde, could now be oxidized to an appreciable extent during the first 24-hr. incubation period. Concentrations above 1,750 p.p.m. may be oxidized, but the efficiency may decrease for a 24-hr. aeration period, as the highest oxidation rates obtained thus far have been

around 190 p.p.m. B.O.D. per hr. At concentrations around 750 p.p.m., the oxidation rate begins to level off after 5 hr. and an aeration period of 12 hr. is needed to effect a 95 per cent reduction in B.O.D.

Effect of Seed Volume Variation

During the oxidation of formaldehyde a flocculent sludge was produced. Several experiments demonstrated that seed volume and sludge concentrations were of great importance in determining the rate of oxidation. The results (Table II) show that as the seed volume was decreased to 5 per cent, a 3-day lag period resulted. The oxidation rate was lower than that at the higher seed concentrations, so that after 5 days only 50 per cent of the formaldehyde had been oxidized.

TABLE II.—Effect of Seed Volume on Rate of Oxidation[1] of Formaldehyde at Concentration of 260 P.p.m.

Days	Seed Volume (%)			
	50	25	10	5
0.8	93	65	34	24
1.75	203	117	50	19
2.75	268	256	94	38
3.75	278	275	232	80
4.75	288	286	266	147

[1] In p.p.m. of O_2 utilized.

When the effectiveness of the supernatant liquor as seed is compared with that of the sludge produced, the latter proves to be better (Table III). Because the sludge formed represents a concentration of formaldehyde-oxidizing organisms, it is to be expected that it would be more effective in causing the oxidation to proceed. This is further borne out by a study of the effect of sludge concentration, expressed as volatile solids (Table IV), showing that as the sludge concentration is increased the oxidation rate increases, although not in direct proportion.

Where supernatant liquor was used continuously as seed material for oxidation of 750 p.p.m., B.O.D. reductions of 95 per cent were obtained for 4 successive transfers; but thereafter a progressive decrease in oxidation efficiency occurred, with the result that after 7 transfers only 8 per cent B.O.D. reduction was obtained after 24-hr. aeration.

TABLE III.—Effectiveness of Sludge as Seed in Oxidation[1] of Formaldehyde at Concentrations of 700 and 930 P.p.m.

Days	700 P.p.m.		930 P.p.m.	
	Supernatant	Sludge	Supernatant	Sludge
0.75	273	662	162	830
1.0	473	710	209	985
1.75	756	720	—	—

[1] In p.p.m. of O_2 utilized.

Nitrogen Requirements

Results obtained with B.O.D.: N ratios varying from 15:1 to 100:1 show that no ammonia nitrogen was present in the effluent after 24-hr. aeration until the B.O.D.: N ratio was 30:1 or lower. The nitrogen utilization was 20 p.p.m., corresponding to a B.O.D.: N ratio of 40:1. Where a formaldehyde waste contains no nitrogeneous material, its addition to satisfy this ratio is necessary if treatment by biological oxidation is considered.

Effect of Buffer Addition

During the oxidation of formaldehyde, acid intermediaries are produced,

TABLE IV.—Effect of Sludge Concentration on Oxidation[1] Rate

Hours	Seed Expressed as Volatile Solids (p.p.m.)			
	4,180	2,000	1,045	418
0.5	121	89	47	32
1.0	192	153	79	50
2.5	325	250	133	83
4.0	531	493	224	144
8.0	838	850	534	322
20.0	913	968	815	766

[1] In p.p.m. of O_2 utilized.

TABLE V.—Effect of Buffer Concentration on Oxidation[1] Rate and pH[2] over a 24-Hour Period

Hours	Buffer Concentration (%)							
	1.5		1.2		0.8		0.5	
	O_2 Util.	pH	O_2 Util.	pH	O_2 Util.	pH	O_2 Util.	pH
1	156	6.5	127	6.5	112	6.0	55	5.6
2	305	6.3	248	6.2	185	4.7	69	4.1
3.5	526	6.3	390	6.1	236	4.6	76	3.9
5	675	6.5	542	6.3	284	4.7	80	3.8
22	900	7.4	968	7.4	967	7.4	91	3.8

[1] In p.p.m. O_2 utilized.
[2] Initial pH 7.4.

which in the absence of adequate buffer concentrations can reduce the pH from neutral to values as low as 3.8 after several hours' aeration. Below pH 6 the oxidation rate is decreased; at pH 3.8 the oxidation is halted.

The results (Table V) show that as the buffer concentration was decreased from 1.5 to 0.5 per cent, the pH fell to 4.1 after 2 hr. and did not recover, resulting in only 10 per cent oxidation during the 24-hr. period. At the higher buffer concentrations the pH dropped initially, but recovered to its initial value during the 24-hr. period.

Effect of Seed Storage

In treating an industrial waste containing formaldehyde, there is the possibility of intermittent discharge. It was considered desirable, therefore, to know the effect of seed storage on its subsequent formaldehyde oxidizing ability. Seed material was divided into 6 fractions and used on successive days to oxidize 750 p.p.m. formaldehyde. Storage under quiescent conditions, except for one hand shaking each day for periods up to 5 days, did not significantly affect the oxidizing ability of the seed material. The average initial oxidation rate was 105 p.p.m. per hr., with little variation from the average during the 5-day period.

Settling Rate of Seed Sludge

A study was made to determine the rate of settling and the final volume occupied by various sludge concentrations. It was found that 2 min. were required to settle 200-ml. samples in a 250-ml. graduate cylinder. At sludge concentrations varying from 418 p.p.m. to 4,180 p.p.m. volatile solids, the proportion of sample volume occupied by the sludge varied from 2 to 12.5 per cent, respectively.

Microscopic Examination of Seed Material

The sludge formed has a characteristic pink color and when examined microscopically consists of dense aggregates of rod-shaped organisms. Bergey's manual (6) describes an organism, called *Bacterium methylicum*, first observed in 1892 by Loew. It is distinguished by its ability to decompose formaldehyde and formic acid salts with the formation of a reddish pellicle. It also grows well in a medium containing 0.4 per cent methyl alcohol. The cells are described as short thick rods. The ability of the adapted flora to oxidize methyl alcohol was studied at 500-p.p.m. concentration. In 24 hr., 96 per cent of the added methyl alcohol was oxidized.

Discussion of Results

The results show the usefulness of the direct method in studying the toxicity of a particular compound formaldehyde, and the development of an adapted flora capable of producing a high rate of oxidation. The direct measurement of oxygen utilization provides a good index of the activity of the seed material at different stages in its development and under different environmental conditions. Although the dilution method could be used to determine this activity, the time required by the 5-day incubation period is eliminated by using the direct method.

Adaptation takes place readily, and after several transfers the characteristic pink flocculent growth appears. It is accompanied by high rates of oxidation, which make possible B.O.D. reductions of 95 per cent at formaldehyde concentrations ranging up to 1,750 p.p.m. with an aeration period of 24 hr. or less.

Conditions for treatment of formaldehyde wastes by aeration are suggested by the results obtained. The re-use, as seed material, of sludge formed during oxidation is necessary for optimum results. As the sludge settles readily, no difficulties may be expected in separating it from the aeration tank effluent. Storage of the sludge does not affect its ability to decompose formaldehyde, making possible the treatment of waste discharged intermittently. Nitrogen must be added to satisfy a B.O.D.: N ratio of 40: 1 if it is lacking in the plant waste. Careful pH control is necessary, because at pH values below 6 the seed material begins to lose activity and it is lost completely when the pH drops to 4. Oxidation rates of 190 p.p.m. B.O.D. per hr. have been obtained and if maintained require 5-hr. aeration for 750 p.p.m. formaldehyde and 12-hr. aeration for 1,750 p.p.m. Actually, the initial rates level off so that aeration periods of 12 and 24 hr., respectively, are required.

Conclusions

1. A concentration of 135 to 175 p.p.m. formaldehyde is toxic to the biochemical oxidation of sewage.

2. By a process of adaptation and selection the oxidizable concentration of formaldehyde was increased from 135 p.p.m. to 1,750 p.p.m.

3. The percentage of formaldehyde oxidized during the first 24 hr. increased simultaneously from zero to 95 per cent as a result of this process.

4. The sludge formed during oxidation is more effective than supernatant liquor in oxidizing formaldehyde.

5. Nitrogen must be added to satisfy a B.O.D.: N ratio of 40: 1 before ammonia nitrogen is found in the effluent.

6. Addition of buffer is necessary to prevent excessive lowering of pH and reduction of oxidation rates.

7. Storage of seed material for periods up to 5 days does not affect its ability to oxidize formaldehyde.

8. The sludge formed appears to consist of dense aggregates of *Bacterium methylicum* and has a characteristic pink color.

9. The sludge settles rapidly, the final volume depending on the concentration of sludge.

Acknowledgment

This investigation was supported by a research grant (R. G. 2143) from the Division of Research Grants and Fellowships, National Institutes of Health, U. S. Public Health Service.

References

1. Dickerson, B. W., "High-Rate Trickling Filter Operation on Formaldehyde Wastes." THIS JOURNAL, **22**, 4, 536 (Apr., 1950).
2. "Rogers' Manual of Industrial Chemistry." 6th Edition, p. 1674 (1942).
3. Gilcreas, F. W., "Inhibition of Sludge Digestion by Penicillin Manufacturing Wastes." (abs.) *Sewage Works Eng.*, **17**, 360 (1946).
4. Heukelekian, H., "Use of the Direct Method of Oxygen Utilization in Waste Treatment Studies." *Sewage Works Jour.*, **19**, 5, 875 (Sept., 1947).
5. Caldwell, D. H., and Langelier, W. F., "Manometric Measurement of the Biochemical Oxygen Demand of Sewage." *Sewage Works Jour.*, **20**, 2, 202 (Mar., 1948).
6. "Bergey's Manual of Determinative Bacteriology." 6th Edition, p. 643 (1948).

BIOLOGICAL TREATMENT OF KRAFT MILL WASTES

W. A. Moggio and H. W. Gehm

Resident Engineer at Louisiana State University and Technical Adviser, respectively, National Council for Stream Improvement (of the Pulp, Paper, and Paperboard Industries), New York, N. Y.

Introduction

The feasibility of treating kraft mill wastes by storage or lagooning on a full-scale installation has been demonstrated in several instances (1) (2). Further laboratory (3)(4) and plant-scale (5) studies have yielded an insight into the mechanics of this method of kraft mill waste treatment. Based on the above information and data it has been established that the reduction in the B.O.D. of stored kraft mill waste is basically a biochemical process. In practice and in the laboratory this storage process of waste stabilization progresses, in the presence of microorganisms, under aerobic and anaerobic environments, with the anaerobic phase predominating initially and being superseded eventually by the aerobic phase. Under natural conditions of seeding and oxygen adsorption and diffusion the transition from the anaerobic to the aerobic phase, with eventual stabilization of the waste, proceeds at a relatively slow rate.

In order to accelerate the rate of stabilization of kraft pulp and paper mill waste it was felt that the following conditions would have to be satisfied:

1. Elimination of the anaerobic environment.
2. Provision of the proper aerobic organisms in sufficient concentration.
3. Provision of nutrient salts necessary for bacterial metabolism, in which kraft mill waste is notably deficient.

The first condition can be achieved by aeration; the second, by the development of concentrated bacterial seed sludge, which is added to the waste; and the third, by the addition of nitrogen and phosphorus salts such as NH_4Cl and K_2HPO_4 or Na_2HPO_4.

The kraft mill waste used throughout this study was obtained from a large integrated pulp and paper mill whose waste flow totals between 20 and 25 m.g.d. The waste is made up of pulp mill waste, bleach plant waste, and paper mill waste. It also contains the domestic sewage from approximately 1,000 employees, as well as the waste flow from a mill cafeteria. The quantity of air used for aeration was not measured except in one instance. The rate of air application was sufficient to keep the sludge in suspension throughout the duration of the experiment. Seed sludges were developed from kraft mill waste or other media. Those sludges which were not prepared from the mill waste itself were acclimated to the waste by means of

TABLE I.—Key to Containers

Container No.	Seed	Nutrient Salts (p.p.m.)			Aeration (cu.ft./gal./day)
		N	PO_4	K	
S31	Yes	5	2	1.6	0.5
S32	Yes	15	6	4.8	0.5
S33	Yes	None	None	None	0.5
S34	Yes	5	2	1.6	1.0
S35	Yes	15	6	4.8	1.0
S36	Yes	None	None	None	1.0
S37	No	15	6	4.8	1.0
S38	No	None	None	None	1.0

TABLE II.—Tabulation of Results

Day	Container	5-Day, 20° C. B.O.D. (p.p.m.)	pH	Nitrogen (p.p.m.)			PO_4 (p.p.m.)	D.O. (p.p.m.)
				NH_3	Org.	NO_2–NO_3		
0	S31	130	7.16	5.0	2.5	0.2	4.9	3.2
	S32	130	7.08	13.0	2.3	0.3	12.8	1.7
	S33	130	7.09	0.6	1.8	0.0	2.2	1.3
	S34	130	7.34	5.1	2.3	0.0	4.5	4.0
	S35	130	7.32	12.4	2.6	0.0	12.5	1.8
	S36	130	7.41	0.6	2.6	0.1	2.2	1.6
	S37	130	7.29	13.1	2.0	0.1	9.1	1.6
	S38	130	7.18	0.6	1.5	0.0	2.4	1.6
1	S31	94	7.45	—	—	—	—	3.4
	S32	94	7.26	—	—	—	—	3.3
	S33	127	7.50	—	—	—	—	3.6
	S34	100	7.53	—	—	—	—	5.1
	S35	97	7.37	—	—	—	—	5.8
	S36	129	8.06	—	—	—	—	5.5
	S37	99	7.80	—	—	—	—	4.6
	S38	134	8.11	—	—	—	—	5.6
4	S31	15	7.51	0.2	1.5	0.1	1.6	1.2
	S32	10	7.66	7.5	2.2	0.2	7.2	4.1
	S33	73	7.40	0.3	1.3	0.8	1.6	0.9
	S34	13	7.80	0.0	1.7	0.1	1.9	2.9
	S35	13	7.74	8.0	2.0	0.2	7.5	4.0
	S36	67	7.73	0.2	0.8	0.0	3.1	3.9
	S37	14	7.54	8.7	1.9	0.0	4.3	4.3
	S38	68	7.57	0.2	0.8	0.0	1.9	3.2
7	S31	14	7.77	—	—	—	—	5.4
	S32	10	7.83	—	—	—	—	5.9
	S33	63	7.41	—	—	—	—	1.6
	S34	10	7.77	—	—	—	—	5.6
	S35	11	7.75	—	—	—	—	6.0
	S36	48	7.59	—	—	—	—	4.8
	S37	15	7.55	—	—	—	—	4.9
	S38	31	7.51	—	—	—	—	4.7
11	S31	7.7	7.82	0.2	1.7	0.3	3.5	6.0
	S32	3.2	7.46	4.6	2.7	2.0	9.7	5.9
	S33	22	7.63	0.2	1.2	0.1	1.3	4.4
	S34	2.7	7.83	0.1	1.8	0.7	3.3	6.2
	S35	8.1	7.77	4.2	3.0	2.9	8.3	6.3
	S36	15	7.80	0.1	1.1	0.0	0.8	5.8
	S37	8.2	8.06	0.5	1.5	0.1	7.8	6.4
	S38	20	8.08	0.2	1.1	0.0	0.5	6.2

gradually increasing additions of the waste to the seed sludge. This was done in all instances except when it was desired to study the effect of acclimatization. All experiments were conducted at room temperatures, varying from 23° to 34° C.

Preliminary Experiments

The first application of aeration to a seeded, supplemented kraft mill waste was made in accordance with the summary in Table I. The bacterial seed used in this experiment was collected from storage experiments previously performed and is derived from organisms occurring naturally in the kraft waste itself. Suspended solids of the seed sludge-kraft waste mixture did not exceed 200 p.p.m.

Table II is a tabulation of the analytical data and Table III and Figure

TABLE III.—Comparison of Per Cent B.O.D. Removal

Aeration (days)	Container							
	S31	S32	S33	S34	S35	S36	S37	S38
0	0	0	0	0	0	0	0	0
1	27.7	27.7	2.3	23.1	25.4	0.8	23.8	0
4	88.5	92.3	43.8	90.0	90.0	48.5	89.2	47.7
7	89.2	92.3	51.5	92.3	91.5	63.1	88.5	76.2
11	94.1	97.5	83.1	97.9	93.8	88.5	93.7	84.7

1 give comparisons of the B.O.D. removals achieved.

Examination of the B.O.D. results (Table III and Figure 1) shows that the samples fall into two groups; S33, S36, and S38 comprise the first group, which yielded appreciably lower B.O.D. removals as compared to the second group, made up of the remaining samples. The factor common to all samples of the first group (S33, S36, and S38) is the absence of added nutrient salts, whereas the samples of the second group all contained the added nutrient salts. The effect of the presence or absence of bacterial seed is inconclusive, as the sample containing all the added nutrient salts but no added seed (S37) yielded results comparable to the samples with both added seed and salts present. It is likely, however, that sufficient numbers of microorganisms were present in the waste itself (from the plant domestic sewage) to overcome any deficiency in bacterial seed concentration in this instance.

Apparently, kraft mill waste lends itself to biological treatment at an accelerated rate. This is accomplished through bacterial seeding, the additions of small quantities of nutrient salts (5 p.p.m. N, 2 p.p.m. PO_4, and 1.6 p.p.m. K), and the application of quantities of air as little as 0.5 cu. ft. per gal. of waste per day. B.O.D. re-

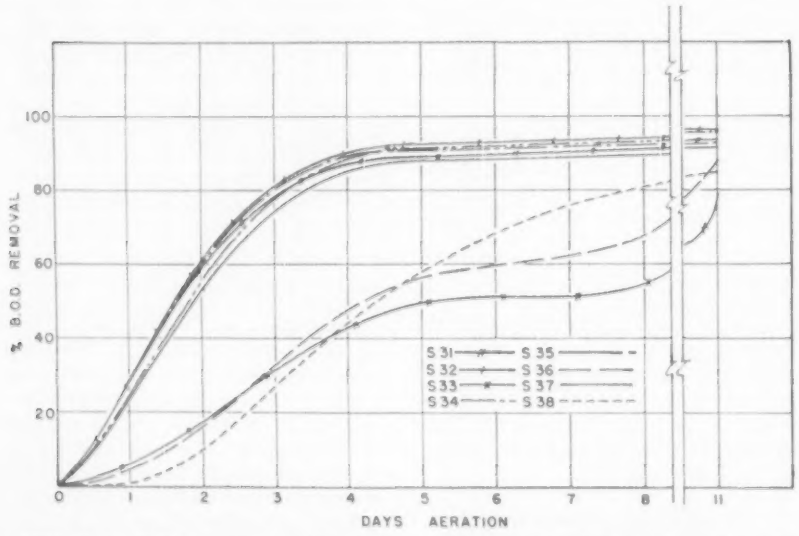


FIGURE 1.—B.O.D. removals with various combinations of seeding and nutrient salts.

movals as high as 90 per cent are achieved with 4-day aeration. Compared to B.O.D. removals by storage alone (4), where 90 per cent B.O.D. removals were achieved in about 40-day storage, only one-tenth the time is necessary.

Effect of Bacterial Seed and Chemical Nutrient Addition

A further acceleration in the rate of B.O.D. removal from kraft mill waste would be still more desirable. Based on the preceding experiment, it was felt that an increase in the amounts of bacterial seed and aeration, in the presence of the added nutrient salts, would accomplish the desired results. An experiment meeting the above conditions was devised, using a seed sludge derived by concentrating the sludge from the preceding experimental run. The samples used were prepared in accordance with the schedule shown in Table IV. Suspended solids concentration of the seed sludge-kraft waste mixture was approximately 400 p.p.m. The B.O.D. results and the per cent B.O.D. removals are given in Table V.

Examination of Table V shows the marked effect of the presence and absence of nutrient salts (A3 and A4) and presence and absence of both the bacterial seed and the nutrient salts (A3 and A5). The negative B.O.D. removal results of sample A5 are probably due to evaporation occurring during aeration. The results for A5 are evidence of the small effect simple aeration alone has on the removal of B.O.D. from kraft mill waste. B.O.D. removals increase substantially when the aeration is supplemented by bacterial seed addition; the increase in B.O.D. reduction is still greater when aeration is supplemented by bacterial seed and nutrient salt addition.

TABLE IV.—Key to Containers

Container No.	Seed	Nutrient Salts (p.p.m.)			
		N	PO_4	Mg	K
A3	Yes	10	5	5	4.1
A4	Yes	None	None	None	None
A5	No	None	None	None	None

TABLE V.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
0	A3	141	0
	A4	140	0
	A5	126	0
1	A3	127	9.9
	A4	132	5.7
	A5	—	—
2	A3	121	14.2
	A4	130	7.1
	A5	—	—
4	A3	122	13.4
	A4	130	7.1
	A5	—	—
6	A3	96	31.9
	A4	122	12.9
	A5	136	− 7.9
24	A3	17	87.9
	A4	84	40.0
	A5	130	− 3.2
48	A3	16	88.7
	A4	47	66.4
	A5	98	22.2

Sources of Bacterial Seed

It has been demonstrated by the preceding experiments that it is possible to accelerate appreciably the rate of B.O.D. removal from kraft mill waste by aeration of the waste which has been supplemented with seed sludge and chemical nutrients. Up to this time the source of the organisms used has been the waste itself, which is known to contain domestic sewage. Due to the resemblance of this treatment process to the activated sludge process, the use of activated sludge derived from domestic sewage as a source of the seed sludge organisms was in-

vestigated. Such an investigation should serve two purposes: first, it would establish a good source of organisms (domestic sewage) which is easily available; and second, it would furnish information concerning the possibility of treating kraft mill waste combined with domestic sewage in a municipal or industrial sewage treatment plant employing the activated sludge process.

Three types of bacterial seed were used in this study. The mill seed sludge was derived entirely from the waste itself and the activated sludge was prepared from domestic sewage. The waste acclimated activated sludge was prepared by adding increasing quantities of kraft waste to activated sludge. Suspended solids concentration of the seed sludge-kraft waste mixture was approximately 1,000 p.p.m.

TABLE VI.—Key to Containers

Container No.	Type of Seed	Nutrient Salts (p.p.m.)		
		N	PO_4	K
A6	Mill waste sludge	10	5	4.1
A7	Waste acclimated activated sludge	10	5	4.1
A8	Activated sludge	10	5	4.1

The schedule of the samples is summarized in Table VI. The results, shown in Table VII and Figure 2, indicate that it is possible to oxidize kraft mill waste using activated sludge which has been derived from domestic sewage, provided sufficient time is allowed for the activated sludge to become acclimated to the waste. Although the waste acclimated activated sludge and the unacclimated activated sludge lag behind in B.O.D. removals, the 24-hr. aeration results show that equivalent removals are obtainable.

The possibility existed that the results obtained in the preceding experiment were not the result of the activated sludge organisms, but the result of organisms not common to sewage which may have been introduced through the medium of the unsterile mill waste. To eliminate this possibility, sterile mill waste was substituted for the unsterile waste in the process of acclimating a fresh batch of activated sludge and in the experimental run itself. The procedure used in this new experiment was identical with the previous one with the exception noted. A description of the samples used is summarized in Table VIII. The suspended solids concentrations of the seed sludge-mill waste mixture was approximately 1,000 p.p.m. B.O.D. re-

TABLE VII.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
0	A6	153	0
	A7	153	0
	A8	153	0
1	A6	133	13.1
	A7	130	15.0
	A8	142	7.2
2	A6	101	34.0
	A7	123	19.6
	A8	129	15.7
4	A6	62	59.5
	A7	97	36.6
	A8	125	18.3
6	A6	30	80.4
	A7	67	56.2
	A8	112	26.8
24	A6	22	85.6
	A7	22	85.6
	A8	22	85.6

TABLE VIII.—Key to Containers

Container No.	Type of Seed	Nutrient Salts (p.p.m.)		
		N	PO_4	K
A10	Mill waste sludge	10	5	4.1
A11	Waste (sterile) acclimated activated sludge	10	5	4.1
A12	Activated sludge	10	5	4.1

sults and comparisons of the per cent B.O.D. removals are tabulated in Table IX.

The results of this experiment confirm those of the preceding one, with the waste acclimated activated sludge (A11) exhibiting good B.O.D. removals and equalling the B.O.D. removals of the sludge derived from mill waste alone (A10) at the end of 6 hr.

On the basis of the results of the last two experiments described, the probable source of the organisms responsible for the oxidation of kraft mill waste, which were derived from the waste itself, is domestic sewage. It has also been demonstrated that, regardless of the source of beneficial organisms in the waste itself, it is possible to develop from domestic sewage a seed sludge capable of biologically purifying kraft mill waste.

Role of Phosphorous and Nitrogen Salts

The effect of the nutrient salts was studied, individually and combined, for the purpose of determining if it would be possible to eliminate one or the other from the process. Due to the chemical composition of the waste itself the role of potassium, sodium, and chloride ions was discounted, as these ions are naturally present in the waste. Of the added nutrient salts, only the phosphate and ammonium ions were considered critical, as might be expected in a process involving biochemical oxidation.

The seed sludge used in this series of studies was derived from fortified kraft mill waste. In order to remove, as nearly as possible, the excess phosphate and ammonium ions from the built-up sludge it was necessary to settle the sludge, wash with distilled water, settle, and decant several times, followed by centrifuging and decanting. However, due to the composition of the waste used in these studies it was probably impossible to obtain a seed sludge-kraft waste mixture entirely free of either phosphate or ammonium ions. Analyses of the kraft

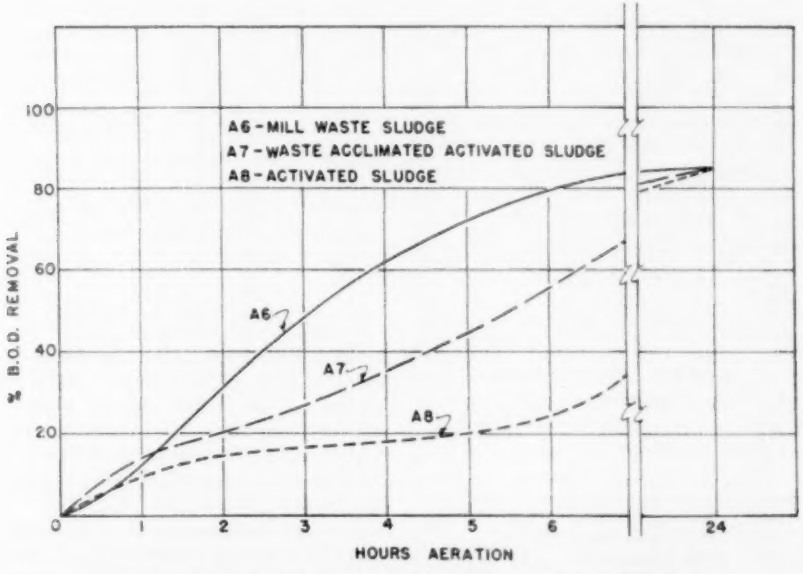


FIGURE 2.—B.O.D. removals with various types of seeding.

TABLE IX.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
0	A10	197	0
	A11	197	0
	A12	197	0
1	A10	182	7.6
	A11	194	1.5
	A12	197	0
2	A10	167	15.2
	A11	170	13.7
	A12	197	0
4	A10	102	48.2
	A11	128	35.0
	A12	173	12.2
6	A10	70	64.5
	A11	72	63.5
	A12	98	50.2
24	A10	18	90.8
	A11	29	85.3
	A12	91	53.8

waste alone indicated that it contains approximately 3 p.p.m. total nitrogen (as N) and 1 p.p.m. PO_4 (as PO_4), which were probably present due to the domestic sewage content, raw process water, and wood extractives.

The first of these studies was prepared in accordance with the procedure outlined in Table X. The suspended solids concentration in the seed sludge-kraft mill waste mixtures was 1,630 p.p.m. The results obtained are summarized in Table XI and per cent B.O.D. removals are plotted in Figure 3.

It is interesting to note from the results that the waste samples containing nitrogen (A20, A22), in the presence or absence of phosphates, yielded similar high B.O.D. removals throughout, whereas the waste supplemented with phosphate alone lagged behind in B.O.D. removals until 24-hr. aeration. In spite of the lag, however, appreciable B.O.D. removals were attained using phosphate as the sole nutrient. It is also of interest to note that waste fortified with a nitrogen salt alone yielded B.O.D. removals of the same magnitude as were obtained from a combination of phosphate and nitrogen salts.

TABLE X.—Key to Containers

Container No.	Type of Seed	Nutrient Salts (p.p.m.)	
		N	PO_4
A20	Mill waste sludge	10	None
A21	Mill waste sludge	None	5
A22	Mill waste sludge	10	5

TABLE XI.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
0	A20	122	0
	A21	116	0
	A22	120	0
1	A20	93	15.5
	A21	101	12.9
	A22	103	14.2
2	A20	81	33.6
	A21	85	26.7
	A22	85	29.2
4	A20	42	65.6
	A21	63	45.6
	A22	52	56.7
6	A20	15	87.7
	A21	47	59.5
	A22	17	85.8
24	A20	9	92.6
	A21	10	91.4
	A22	6	95.0

In the course of the above experiment it was noted that the character of the sludge formed during aeration of the phosphate supplemented waste (A21) differed from that of the ammonium and phosphate-ammonium supplemented wastes. In the latter instance the sludge was of a granular, flocculent nature, whereas in the former the sludge was of a stringy nature.

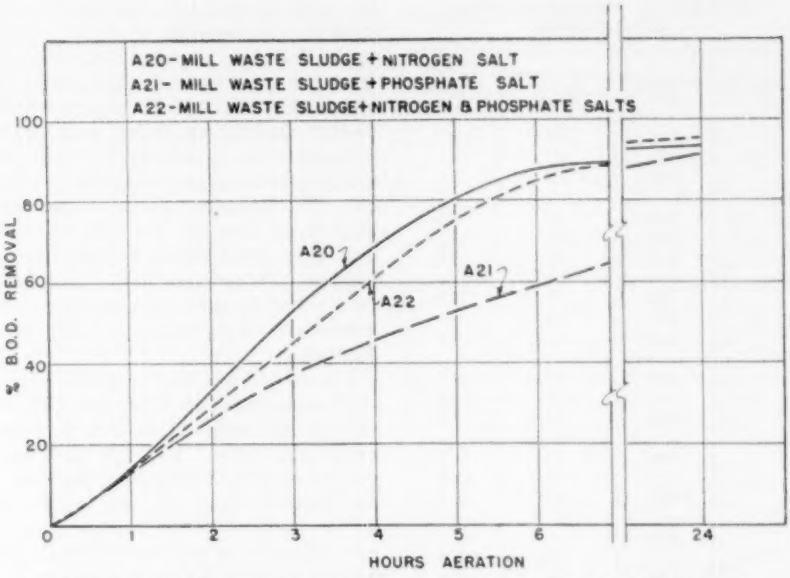


FIGURE 3.—B.OD. removals with mill waste sludge seed and added nutrients.

The settling characteristics of all sludges were equally good.

Based on the observation of the results and differences in physical character of the sludges obtained in the preceding experiment, the possibility was investigated that a waste supplemented with a phosphate salt alone and seeded with sludge developed from phosphate supplemented waste might be capable of biologically oxidizing kraft mill waste efficiently. Interest in such a possibility stems from a consideration of the economies of phosphate versus nitrogen supplementation of kraft mill waste.

TABLE XII.—Key to Containers

Container No.	Type of Seed	Nutrient Salts (p.p.m.)	
		N	PO_4
A30	N supplemented mill waste sludge	10	None
A31	PO_4 supplemented mill waste sludge	None	5
A32	N–PO_4 supplemented mill waste sludge	10	5

Three types of seed sludges were prepared and samples set up in the manner outlined in Table XII. The suspended solids concentration of the seed sludge-kraft mill waste mixtures was 720 p.p.m. in all samples. The B.O.D. results and per cent removals are given in Table XIII.

The results follow the same general pattern as those of the preceding experiment, the only difference being in the magnitude of the B.O.D. removals. The difference was probably due to the difference in suspended solids concentration of the seed sludge-kraft waste mixtures (1,630 p.p.m. versus 720 p.p.m.).

In order to check the effect of seed sludge concentration on the rate of B.O.D. removal, the preceding experiment was repeated using a higher concentration of suspended seed sludge solids. Table XIV summarizes the conditions of the experiment. Suspended solids concentrations of the

TABLE XIII.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
0	A30	101	0
	A31	101	0
	A32	102	0
1	A30	91	9.9
	A31	96	5.0
	A32	98	3.9
2	A30	79	21.8
	A31	94	6.9
	A32	94	7.9
4	A30	71	29.7
	A31	81	19.8
	A32	76	25.5
6	A30	69	31.7
	A31	72	28.7
	A32	68	33.3
8	A30	51	49.5
	A31	64	36.6
	A32	59	42.1
24	A30	24	76.2
	A31	47	53.5
	A32	20	80.4

seed sludge-kraft waste mixtures were 1,650 p.p.m. for samples A40 and A41, and 950 p.p.m. for sample A42. The results are summarized in Table XV; per cent B.O.D. removals are plotted in Figure 4.

The results of the last three experiments (Tables XI, XIII, and XV) demonstrated that the B.O.D. of seeded and aerated kraft mill waste may be removed by the use of phosphate salt supplementation alone. The rate of B.O.D. removal during the first 8 hr. of aeration is lower than in the case of the nitrogen salt and mixed salt supplementation, but equally high removals are obtained with 24-hr. aeration periods.

Effect of Suspended Seed Sludge Solids Concentration

In order to evaluate the role played by the concentration of seed sludge in the seed sludge-kraft mill waste mixtures in the removal of B.O.D. from kraft mill waste, Figure 5 was prepared from the experimental data presented above. Per cent B.O.D. removals were plotted against suspended seed solids concentrations of the mixed liquors for aeration periods ranging from 2 to 24 hr. The samples whose values are plotted all have in common the fact that they were supplemented with a mixture of nitrogen and phosphate salts. The variable remaining in each instance is the suspended solids concentration.

Figure 5 shows that suspended seed solids concentrations have a decided effect on the removal of B.O.D. from kraft mill waste. For the same suspended solids concentration, the longer the aeration time the greater is the B.O.D. removal. Suspended solids concentrations have the least effect in the magnitude of B.O.D. removals for the 2- and 24-hr. aeration periods. Their greatest effect appears to be exhibited during the 8-hr. aeration period and to a lesser degree during the 6- and 4-hr. aeration periods. Using 1,600 p.p.m. suspended seed solids, it is possible to achieve the same per cent B.O.D. removal with 4-hr. aeration (65 per cent) achievable with 8-hr. aeration and 800 p.p.m. suspended seed solids (67 per cent). In the same manner, 1,600 p.p.m. suspended seed solids with 6-hr. aeration (85 per cent removal) will yield results equal to those from 1,000 p.p.m. suspended solids with 8-hr. aera-

TABLE XIV.—Key to Containers

Container No.	Type of Seed	Nutrient Salts (p.p.m.)	
		N	PO_4
A40	N supplemented mill waste sludge	10	None
A41	PO_4 supplemented mill waste sludge	None	5
A42	N-PO_4 supplemented mill waste sludge	10	5

TABLE XV.—Results and Per Cent B.O.D. Removal

Aeration (hr.)	Container No.	pH	Nitrogen (p.p.m.)			5-Day, 20° C. B.O.D. (p.p.m.)	B.O.D. Removal (%)
			NH_3	Organic	NO_2-NO_3		
0	A40	7.37	8.8	2.4	0	128	0
	A41	7.25	0.8	0.8	0	139	0
	A42	7.25	9.2	2.4	0	144	0
1	A40	7.59	—	—	—	80	37.7
	A41	7.47	—	—	—	117	15.8
	A42	7.47	—	—	—	118	18.1
2	A40	7.80	—	—	—	61	52.3
	A41	7.68	—	—	—	99	28.8
	A42	7.68	—	—	—	91	36.8
4	A40	7.92	—	—	—	36	71.9
	A41	7.79	—	—	—	82	41.0
	A42	7.75	—	—	—	64	56.3
6	A40	7.64	—	—	—	24	81.3
	A41	7.80	—	—	—	71	48.9
	A42	7.75	—	—	—	46	68.0
8	A40	7.65	0.4	3.6	3.0	14	89.1
	A41	8.00	0.8	1.4	0.6	57	59.0
	A42	8.01	2.8	2.6	1.4	23	84.0
24	A40	8.12	0.4	3.2	3.4	15	88.3
	A41	8.12	0.4	1.8	0.2	24	82.8
	A42	7.92	0.4	3.6	1.6	12	91.7

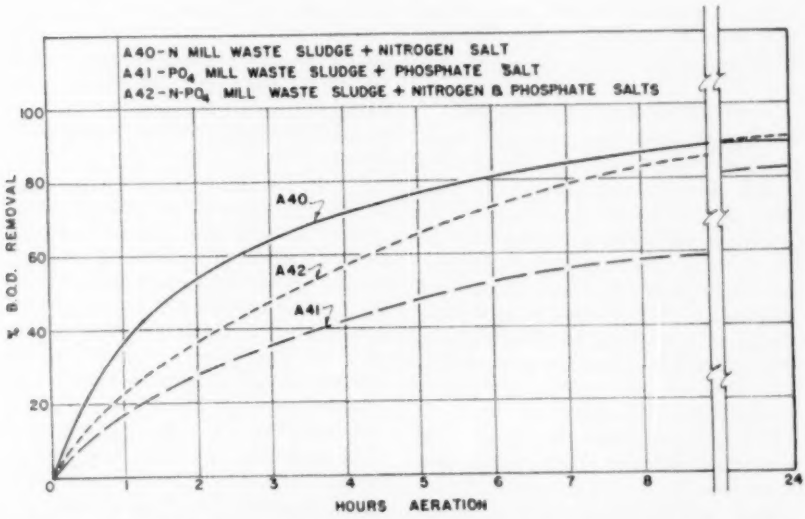


FIGURE 4.—B.O.D. removals with nutrient supplemented mill waste sludge seed plus added nutrients.

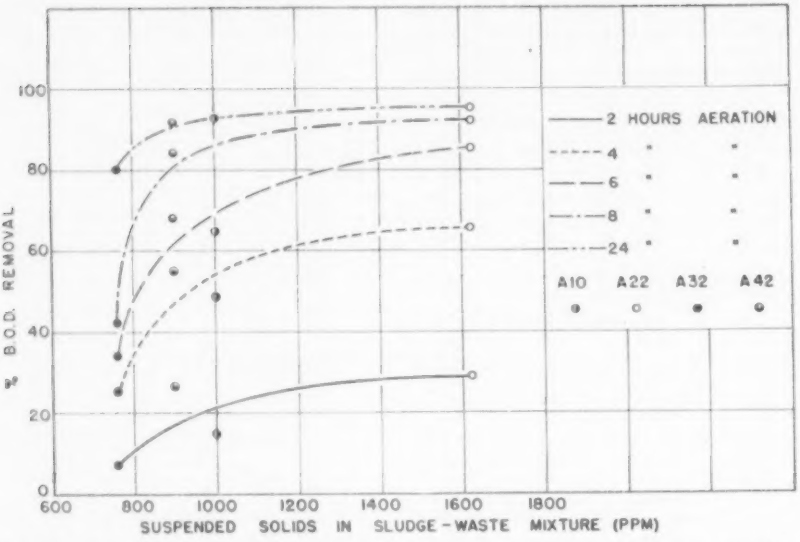


FIGURE 5.—Relationship between B.O.D. removal and suspended solids concentration.

tion, or 800 p.p.m. suspended solids with 24-hr. aeration. The plotted data also show that with suspended solids concentrations of 1,000 p.p.m. or greater, aeration periods of only 8-hr. duration will yield B.O.D. removals almost equal to aeration periods of 24-hr. duration.

Summary and Conclusions

1. Kraft mill waste, fortified with nitrogen and phosphate salts and seeded with organisms derived from kraft mill waste itself, lends itself to biological oxidation using as little as 0.5 cu. ft. of air per gallon of waste per day. Using suspended seed solids concentrations of approximately 200 p.p.m., it is possible to obtain B.O.D. removals at a rate 10 times greater than that obtained with unfortified and unaerated kraft mill waste.

2. Supplementation of kraft mill waste with nitrogen (10 p.p.m. N) and phosphate (5 p.p.m. PO_4) salts with increased rates of aeration and increased seed sludge resulted in a further decrease in time necessary for the oxidation of kraft mill waste, equivalent results being obtained in 6 to 8 hr. of aeration as compared to 4 days of aeration.

3. Using both unsterilized and sterilized kraft mill waste it is possible to obtain and acclimate from domestic sewage aerobic organisms equally capable of oxidizing kraft mill waste in the same manner as the aerobic organisms derived initially from the kraft waste itself.

4. Supplementation of seeded kraft mill waste with a phosphate salt alone, a nitrogen salt alone, and a combination of both salts yielded B.O.D. removals of the same magnitude with 24-hr. aeration periods. For aeration periods of 8 hr. or less the rate of B.O.D. removal was greater for the seeded kraft waste supplemented with the nitrogen salt, either alone or in combination with the phosphate salt. The B.O.D. removals with 8-hr. aeration periods were only slightly lower than those obtained with 24-hr. aeration periods.

5. The characteristics of the several

seed sludges developed differed somewhat in physical appearance. The seed sludge developed by phosphate supplementation alone was of a stringy nature, whereas the seed sludges developed by nitrogen supplementation alone and nitrogen-phosphate supplementation were of a granular, flocculent nature, resembling activated sludge. It was noted also, that the increase in concentration of the seed sludges took place at a low rate, thereby making it unnecessary to waste large quantities of excess sludge, so that the handling and disposal of excess sludge would become a relatively minor problem.

6. Suspended solids concentrations in seed sludge-kraft mill waste mixtures play an important role in the rate of oxidation of kraft mill waste. The greater the concentration of suspended solids in the mixed liquor, the greater is the rate of B.O.D. removal. Concentrations of suspended solids below 1,000 p.p.m. require appreciably longer aeration periods. With concentrations of 1,600 p.p.m., 60 to 90 per cent B. O.D. removals can be achieved with aeration periods of 4 to 8 hr. duration. Such concentrations of suspended solids are in the range commonly used in the biological oxidation of domestic sewage by the activated sludge process.

References

1. Carpenter, C., and Porter, C. C., "Experience in Purifying Kraft Pulp Mill Waste." Tech. Bull. 13, Nat. Council for Stream Improv. (1947).
2. Crawford, S. C., "Ponding of Sulfate Mill Wastes." *Sewage Works Jour.*, **19**, 4, 621 (July, 1947).
3. Moggio, W. A., "Storage Studies on Kraft Mill Wastes." Tech. Bull. 19, Nat. Council for Stream Improv. (1948); *Eng. Exp. Sta. Bull.*, Series 13, Louisiana State Univ. (1948).
4. Moggio, W. A., unpublished data.
5. Porter, C. C., personal communications.

DEARBORN, MICH., GARBAGE GRINDER ORDINANCE

Recent action by the City Council of Dearborn, Mich., requires all commercial food-handling establishments, as well as all multiple-family dwellings of more than four units, to install garbage grinders, according to a report by the American Public Works Association. Under the ordinance, existing buildings in these categories are given one year in which to install grinders.

The action was taken as a result of a study made by the Dearborn Public Works Department, which showed that city-wide use of household garbage grinders would save the city about $190,000 a year by eliminating garbage collection services. City officials estimate that the city's sewage system can handle the additional ground wastes without expansion.

TREATMENT OF PLATING WASTES AT ELECTRIC AUTO-LITE PLANT, LOCKLAND, OHIO *

By Allen Reed

Chemist, Electric Auto-Lite Co., Lockland, Ohio

This paper deals with a plating waste treatment system installed to handle water from a large industrial setup plating various metals with bright and corrosion resistant finishes. Because waste water treatment is a topic of current interest throughout the country, it is felt that the experience in establishing the treatment system should be available for the guidance of anyone who may desire to investigate this type of operation. The treatment plant (Figure 1) has been based on the segregation of the waste waters into the various types so that each type can be treated independently. A final mixing and treatment then results before the water is discharged to the local stream.

The Electric Auto-Lite Company has long been interested in the treatment of waste water from plating departments. Work has been accomplished by the Die Cast Division (Woodstock, Ill.) in connection with the Illinois Sanitary Water Board. A report on fish toxicity studies of chrome-plating wastes at that plant has been published (1). The company's initial experience in the treating of plating waste water was at the Kings Mills, Ohio, plant, where chemical treatment and settling of the resultant sludge was accomplished using a plan developed through the cooperation of the Ohio Public Health Department.

In August, 1948, the Electric Auto-Lite Company acquired property at Lockland, Ohio, and decided to install a plating operation at this plant. In setting up the plant it was desired to provide for treatment of the plating waste in accordance with the state and federal requirements. The two main problems in setting up a waste water disposal system are: first, what does the waste water consist of as to volume and concentrations; and secondly, what purity is needed for the final water effluent.

The first major problem was the estimation of the amount of water and the concentrations of the impurities to be treated. As the plant was to be new, there were going to be many changes in operating methods. This meant that any data available had to be rechecked and allowances made for the changes. Based on operations at the various plants, the amounts of waste water and concentrations were figured. The concentration of the impurities was obtained by taking the average monthly chemical usage for each setup and assuming that this amount of chemicals is all lost in the waste water. It is believed that this method will provide for the maximum impurities that will ever be obtained under production conditions. Treatment capacity was established so that any setup could operate 24 hr. per day at the calculated flow rates and concentrations.

Segregation of Wastes

As soon as the major problem had been set up as to what the waste water consisted of, it was possible to plan the treatment processes. A meeting was held with plant representatives and engineering and chemical consultants. As a result of the meeting, it was de-

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Conference; Cincinnati, Ohio; June 28–30, 1950.

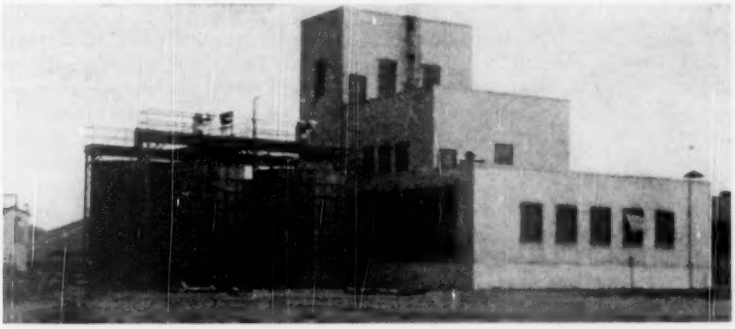


FIGURE 1.—General view of plating waste treatment plant.

cided that the best treatment method would be to provide a sewer system so that the waste waters could be segregated, as follows:

1. Chrome—waste water in which the amount of chrome is in excess of all other items.
2. Alkaline cyanide—waste water in which the amount of cyanide is in excess, plus non-oil cleaners.
3. Acid oily—waste water which is either acid or oily.
4. Electropolish and bonderite—waste water from these two processes.

The initial data were then changed to get the amount of flow through each of the four major sewer lines, to determine the amount of waste that would go from each of the various processes into the specific treatment sewer line.

After the above data had all been summarized and preliminary plans made, they were presented to the State Department of Health for tentative approval in connection with the State's tentative set of stream standards for waste water. In development of present and future plans for the collection, treatment, and disposal of the plating waste waters, three factors largely shaped decisions: flexibility of design, adequacy for eventual needs, and the urgency to complete the initial phase of the program.

For several reasons, flexibility was an essential element of design in planning all facilities. The various units are designed for estimated rather than known loads. Preliminary facilities were laid out so that discharge to the public sewer could be accomplished without sacrifice to the original investment in preliminary facilities. The cost of partial or complete disposal to the sanitary sewer could not be ascertained at the time the initial phases of the program had to be decided upon. Finally, the collection, treatment, and disposal facilities described hereinafter were planned to permit, if advantageous, recycling water to process and recovery of chromium. Reclamation of copper and nickel within the plating process has also been under consideration.

Chemical Treatment

Continuous treatment of a mixture of plating wastes was necessary, as batch treatment was impractical for the flows anticipated. Although lesser quantities of chemical reagents are needed for batch treatment than for continuous treatment, the large volumes of plating wastes expected would have required a tremendous investment in holding tanks.

Normally, tanks containing concentrated solutions are not dumped during working hours. Any such disposals are made on week ends or at the end of the working day. This arrangement allows batch treatment of strong wastes

and results in a fairly uniform volume and composition of waste water. In case of unscheduled dumping of strong concentrated solutions, the plating line supervisor notifies the disposal plant operator, so that the strong waste can be given special treatment in the sumps or reactors (Figure 2). The second line of defense against accidental or necessary strong discharges includes provisions for feeding sodium bisulfite, milk of lime, and chlorine solution to the Accelator. Thus, strong slugs escaping satisfactory treatment in the reactors can be properly conditioned in the Accelator, which has a 2- to 3-hr. retention time. (The Accelator unit was originally installed as part of a water softening system, but has since been converted to an essential part of the waste treatment plant.)

Chromium Treatment

The treatment of chromium wastes is carried out as a two-step process. Sodium bisulfite is mixed as a solution with the chromium line waste at the inlet of the sump. Low pH favors this reduction reaction; if possible, the pH should be maintained below 3. Reduction of hexavalent chromium to the trivalent form continues as the liquid flows through the sump and the reaction tank to the header transporting the mixed waste to the Accelator. At this point, the trivalent chromium is removed by precipitating it as the hydroxide. This reaction takes place by increasing the pH and is accomplished by blending the wastes with the high alkaline cyanide waste and the addition of milk of lime to the Accelator basin. It has been found that efficient removal takes place at a pH between 8 and 9.5. The close control necessary on pH values and chemical feeding indicated the advisability of centralizing all control and indicating apparatus at one central location (Figure 3).

Originally, it was planned to reduce the hexavalent chromium with copperas. However, this method presented numerous problems. Copperas was inconvenient to use, due to the excessive sludge formation in the system. It tends to cake in air over 60° F., giving very troublesome feeding problems. Also, it is very difficult to handle along

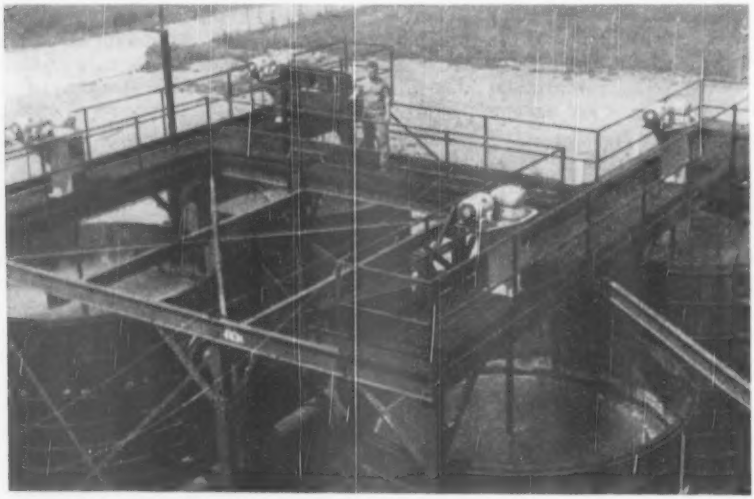


FIGURE 2.—View showing arrangement of stirring mechanisms in reaction tanks of chemical treatment unit.

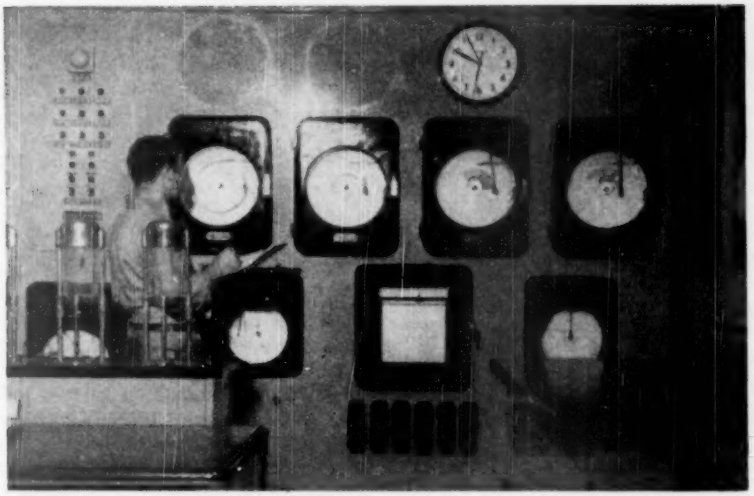


FIGURE 3.—Control panel of plating wastes treatment plant facilitates close checking necessary in pH control, chemical feeds, and sampling. Visual checking of waste is provided for by flow sights on table at left.

with lime in a pneumatic unloading system without encountering additional lumping and caking. In addition, it is expensive, as it was found to require more than 8 lb. of copperas for the reduction of each pound of chromic acid and the resulting sludge adds to the cost of sludge disposal. Much less sodium bisulfite is required to reduce chromium, depending on the pH of the waste. Complete reduction of chromium at low concentrations is possible with sodium bisulfite, but it is not practical with ferrous sulfate.

At the Electric Auto-Lite plant in Woodstock, Ill., where chromium- and cyanide-bearing wastes are mixed, free cyanide has never been detected in the blended effluent. Apparently, the hexavalent chromium oxidizes the free cyanide.

If this is correct, 1 lb. of hexavalent chromium as CrO_3 will oxidize 0.75 lb. of NaCN. As worthwhile savings in chemicals, both sodium bisulfite and chlorine, are possible through this procedure, it will be investigated fully after the disposal plant is in full operation. Of course, there would be many operating difficulties, depending on ideal blending to meet the standards of effluent purity specified by state authorities. Even though such blending were employed, chlorinating and sodium bisulfite feeding equipment must be available in case one or the other plating operations shut down, or to treat excess of one toxic material over the other.

Cyanide Treatment

The cyanide wastes are induced by the copper, nickel, cadmium, and zinc plating installations. This waste water contains copper, zinc, and sodium cyanides and their complexes. The raw plating waste has a pH between 7.5 and 10.5. Chlorine is added to this waste at the inlet to the sump for alkaline oxidation of the cyanides. Additional alkalinity is added at the point of chlorination to restrict the formation of cyanogen chloride and nitrogen trichloride, both very toxic and odorous gases. The excess alkalinity in the cyanide wastes is used to neutralize the acid oily and chrome waste when blended in the

Accelator. The oxidation reaction takes place as the wastes flow through the sump and the two reactor tanks before being blended with the other wastes in the Accelator basin. A chlorine residual of approximately 5 p.p.m. is maintained in the reactor tanks. This high residual has been found necessary to completely destroy cyanide complexes. The excess reducing agent from the chrome wastes reacts with the excess chlorine from the cyanide waste, when blended in the Accelator basin, to give a residual chlorine of 0.1 to 0.3 p.p.m. Inasmuch as the cyanide wastes are the most hazardous wastes, it was believed more practical to maintain an oxidizing condition in the Accelator basin, which has the longest tank retention time in the system.

The reaction of destroying free cyanides proceeds quantitatively and almost instantaneously between free chlorine and free cyanides. Theoretically, 2.73 p.p.m. of Cl_2 and 3.08 p.p.m. of NaOH are required for the oxidation of each p.p.m. of cyanide to cyanate. In practice, however, for continuous treatment more chlorine is needed to convert copper cyanide to a nontoxic substance.

To carry out the complete oxidation of the cyanide to carbon dioxide and nitrogen, an additional 4.09 parts of Cl_2 and 3.08 parts of NaOH are required per part CN. This reaction occurs more slowly; in actual practice excess chlorine also must be added for completion of the reaction.

Acid Oily Treatment

The concentration of oils, fats, and greases in the acid oily waste waters has not exceeded 25 p.p.m. Nevertheless, segregation of oily waste streams has been made to promote the removal of ether soluble material. This facilitates its removal in the receiving sump or the Accelator. Manual skimming of oil from the acid oily sump has been sufficient to keep the ether soluble content of the blended effluent to less than 1 p.p.m. Partial neutralization of the acid waste is accomplished by feeding milk of lime to the acid oily sump before being completely neutralized when blended with other wastes in the Accelator.

Other Metallic Pollutants

All of the other metallic pollutants, such as nickel, copper, zinc, cadmium, etc., have been satisfactorily kept within the limits established by the State Health Department by precipitation as the hydroxide on mixing with lime and by dilution with the completely treated chrome and cyanide wastes.

Sludge Disposal

At present, the sludge is being disposed by lagooning. However, plans are being made for the installation of a mechanical dewatering system. This method, it is believed, will be more economical than having to periodically dredge the lagoons, and will also be much safer from the standpoint of contaminating underground water supplies.

Conclusion

Primarily, the plant has been found to be satisfactory and efficient to operate. Present cost data and chemical analyses have indicated that it will be both economical and safe to reclaim the waste treatment plant effluent for the service water system, and planning is in progress to make the necessary changes.

Reference

1. Klassen, C. W., Hasfurther, W. A., and Young, M. K., "The Toxicity of Hexavalent Chromium to Sunfish and Bluegills." Proc. of Fourth Indus. Waste Conference, p. 229. Engineering Bulletin, Extension Series No. 68, Purdue University (July, 1949).

Stream Pollution

SIMPLIFIED METHOD FOR ANALYSIS OF B.O.D. DATA *

By Edward W. Moore, Harold A. Thomas, Jr., and William Brewster Snow

Associate Professor of Sanitary Chemistry and Associate Professor of Sanitary Engineering, Harvard University, Cambridge, Mass., and Associate Professor of Civil Engineering, Duke University, Durham, N. C.

In the final analysis, the objective in measuring the biochemical oxygen demand of sewages, effluents, or industrial wastes is to determine the effect these wastes will have on the oxygen resources of the stream that receives them. However useful the usual 5-day B.O.D. may be as a practical means of controlling plant operation, it is generally conceded that it does not give an answer to the problem of subsequent oxygen depletion in the stream. What is needed to be known is both the total ultimate oxygen-consuming power of the sewage, effluent, or waste and the rate at which this oxygen-consuming power is exerted with respect to time.

It has long been known (1) that the equation of the unimolecular reaction—

$$y = L(1 - 10^{-kt}) \qquad (1)$$

—represents a good first approximation of B.O.D. exertion with time. In this equation, y represents the oxygen used up at any time t, L represents the ultimate oxygen demand, and k is a measure of the rate at which that oxygen demand is exerted. In this formulation, L and k are the very factors most desired to be known; namely, the total demand and the rate at which it is exerted.

However, in determining these values from actual data, there is at once a serious difficulty. Where the value of L is unknown, the form of the equation makes the determination of the values of k and L from original data impossible, except by methods of statistical analysis involving rather laborious computation. Three such methods have been developed—the Reed-Theriault method (1), the "log-difference" method of Fair (2), and the "slope" method of Thomas (3), each successively less laborious then the preceding one. However, the authors feel that the extensive computations involved have deterred many workers in the field from making full use of the B.O.D. formulation and from expressing their results in terms of the desired parameters, k and L.

It is for this reason that there is presented a fourth method, recently developed, which promises to eliminate in large part the time-consuming computations. It is believed that there is much more information to be extracted from B.O.D. data than is usually extracted from them, and it is hoped that other workers will be encouraged by the relative simplicity of the new method to forsake the 5-day B.O.D., except as a control test, and to measure the strength of sewages, effluents, and wastes in terms of total oxygen demand and rate of exertion. It is believed that if this is done, many of the questions now raised as to the significance of the B.O.D. test eventually can be resolved.

* Presented at Twenty-Third Annual Meeting, Federation of Sewage Works Assns.; Washington, D. C.; Oct. 9–12, 1950.

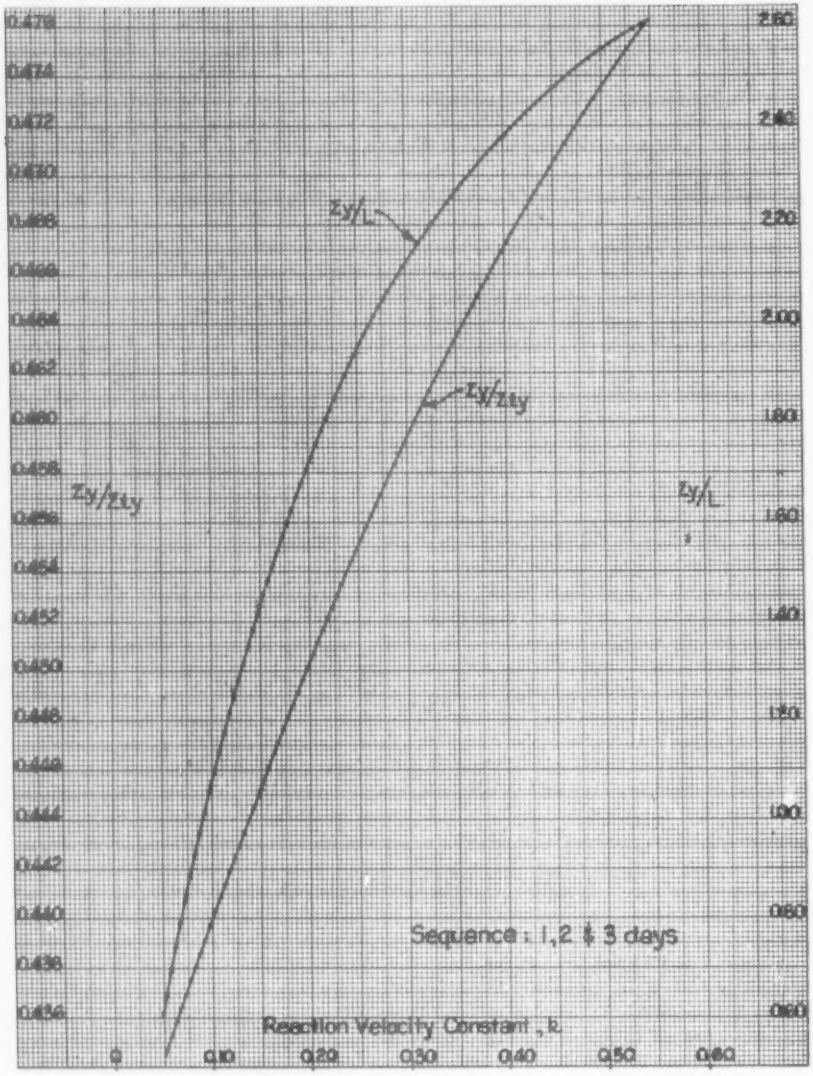


FIGURE 1.—$\Sigma y/L$ and $\Sigma y/\Sigma(ty)$ for various values of k in 3-day sequence.

Nature of the Problem

The essence of the problem is to secure for a series of determined values of B.O.D. at various times that curve conforming to Eq. 1 which best fits these points, and to determine the constants, k and L, of this curve. This is a statistical problem; presumably no one of the values is any better than the others, and all must be taken into account. The curve of best fit for any set of points is commonly considered to be that one for which the sum of the squares of the deviations of the points

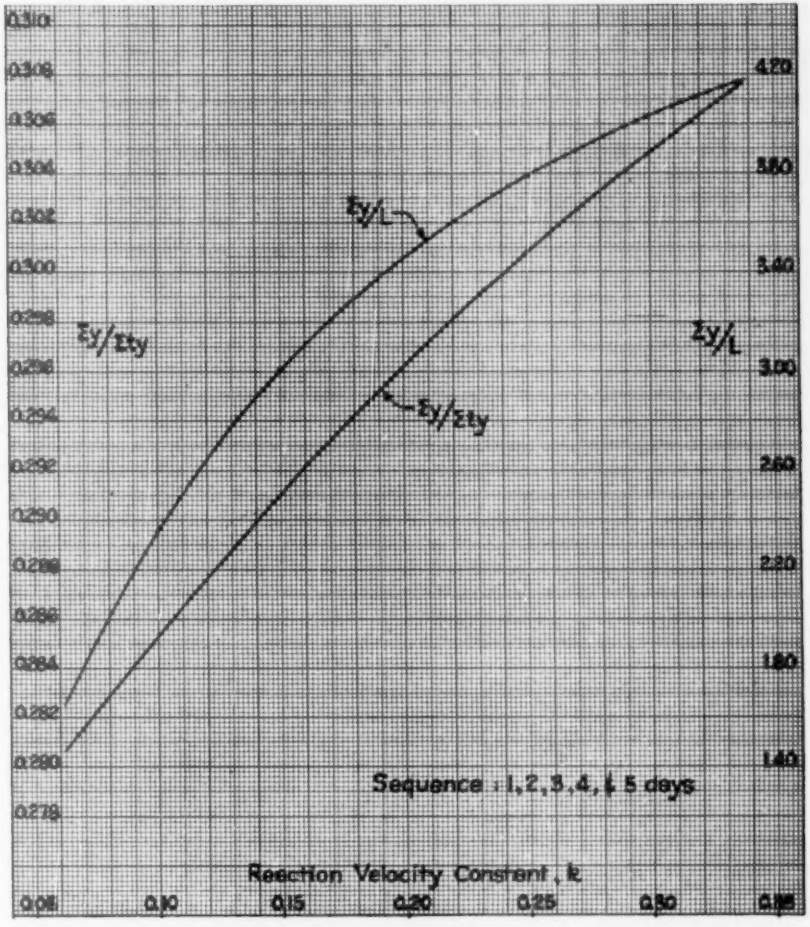


FIGURE 2.—$\Sigma y/L$ and $\Sigma y/\Sigma(ty)$ for various values of k in 5-day sequence.

from the curve is a minimum, and the various methods of analysis previously referred to are based on this principle. The method of analysis described herein arrives at an approximation of this condition by a simpler mathematical route, that of taking the moments of the determined values about the vertical coordinate axis of the curve of B.O.D. *vs.* time. The authors have named it, therefore, the "method of moments." In the presentation of it, first the application of the method will be described and the results obtained will be compared with those obtained by other methods. Then the mathematical principles underlying the method will be presented. The practical application of the method does not require a detailed understanding of its mathematical derivation.

Application of Method

As will be shown in the theoretical development, the sum of a given series

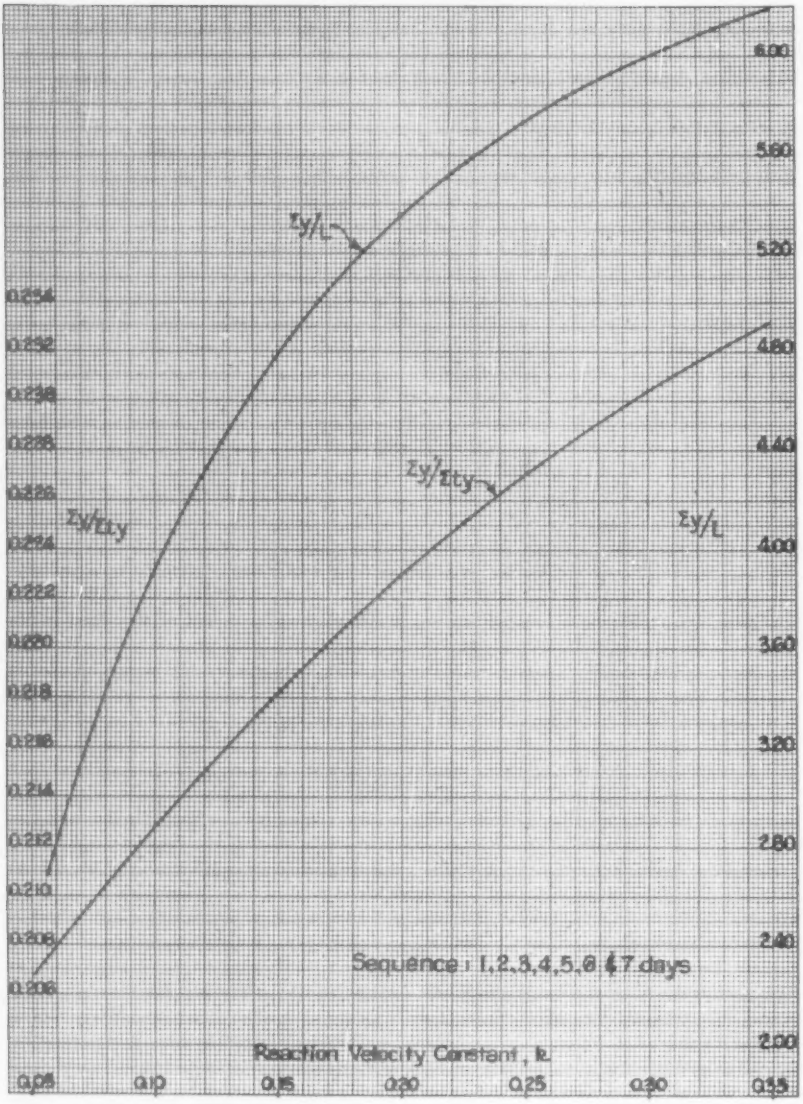


FIGURE 3.—$\Sigma y/L$ and $\Sigma y/\Sigma(ty)$ for various values of k in 7-day sequence.

of observed B.O.D. values, $\sum y$, divided by the sum of the products of the observations and their times, $\sum ty$, is a numerical quantity that depends only on the k value of the sewage observed. Therefore, the value of this ratio can be determined in advance for a range of k values and plotted as a curve of $\sum y/\sum(ty)$ vs. k (Figures 1, 2, and 3). A similar curve can be computed that will yield the value of L (Figures 1, 2, and 3). These curves

apply only to a specified time sequence of observations, which must be selected in advance.

The following example will serve to illustrate the method. The 20° B.O.D. of a raw sewage from a military installation is tabulated below:

Incubation Time, t (days)	Observed B.O.D., y (p.p.m.)	Product, ty
1	82	82
2	112	224
3	153	459
4	163	652
5	176	880
6	192	1,152
7	200	1,400
	$\Sigma y = 1{,}078$	$\Sigma(ty) = 4{,}849$

The first step in the procedure is to compute, for each observed value, the product, ty, of the time and the B.O.D. observed at that time. The sums of the observed B.O.D. values and the products, ty, are then taken. Then the quantity $\Sigma y/\Sigma(ty)$ is computed; in this case, $1{,}078/4{,}849 = 0.2223$.

The time sequence is that shown in Figure 3. Enter this graph on the $\Sigma y/\Sigma(ty)$ scale with the value 0.2223, extend a horizontal line to the curve labeled $\Sigma y/\Sigma(ty)$, and from this point follow a vertical line to the k scale. A value of $k = 0.193$ will be obtained.

Extend the same vertical line to the curve labeled $\Sigma y/L$, and from the intersection follow a horizontal line to the scale labeled $\Sigma y/L$, obtaining a value of 5.27. Hence, $L = \Sigma y/5.27 = 1{,}078/5.27 = 205$ p.p.m.

The values of k and L are thus established by a relatively simple arithmetic operation, followed by reference to the appropriate graph. This graph can be used for any set of data conforming to this time series. It also can be used where the time series is any constant multiple of this series. If, for example, the time sequence in the above example were 2, 4, 6, 8, 10, 12, and 14 days, the computation would still be made as above, using 1, 2, 3, 4, 5, 6, 7 as the values of t, and the values of k and L determined. The k value obtained would then be divided by 2, with the value of L remaining unaffected.

Figures 1, 2, and 3 present graphs for three time sequences believed to be particularly useful. The authors will be glad to assist other workers in preparing graphs for any other time sequences that may be desired. The requirement that the B.O.D. determinations be made on a rigid time schedule to conform accurately to a specified time series is an obvious disadvantage of the method as compared with previous methods making no such demands. However, the great reduction in the labor of computation goes far in compensating for this disadvantage. Minor deviations from the predetermined time sequence have very little effect; for example, the error in the value of k that could be produced by deviations of the order of 0.5 hr. would be at most 2 per cent, and ordinarily would be less than 1 per cent. For deviations of 1 hr., the greatest possible error would be 4 per cent.

Reliability of the Method

The Reed-Theriault method, based as it is on unmodified least-squares procedure, must be regarded as the standard method of computing k and L values for data not exhibiting a lag period. It is necessary, therefore, to test the method of moments against the Reed-Theriault method before accepting it as valid. A number of such comparisons have been made on B.O.D. data accumulated in the course of work on other research problems. Table I gives a comparison of the results obtained by applying the Reed-Theriault, slope, and moment methods to several 7-day series of B.O.D. determinations on a domestic sewage (4). Dilution water, seeding techniques, and procedure for these series were as prescribed in "Standard Methods" (6).

Table II shows comparative results obtained from analyses of B.O.D. data on a few industrial wastes. Length of series varied from 7 to 10 days in these experiments.

TABLE I.—Values of k and L for Domestic Sewage as Determined by Analysis of Data by Various Methods

Experiment No.	Reed-Theriault Method			Slope Method			Moment Method		
	k	L(p.p.m.)	ΣR^2	k	L(p.p.m.)	ΣR^2	k	L(p.p.m.)	ΣR^2
3	0.158	197	248	0.146	204	275	0.165	195	265
5	0.205	171	191	0.192	174	215	0.213	170	194
6	0.192	140	132	0.181	145	186	0.204	141	174
7	0.224	205	250	0.210	212	328	0.231	205	260
10	0.199	199	383	0.177	206	439	0.208	198	410
13	0.194	173	120	0.186	176	120	0.199	172	132
14a	0.262	158	87	0.284	157	139	0.259	159	85
14b	0.255	150	51	0.275	149	95	0.253	150	66
14c	0.191	128	574	0.192	128	574	0.198	129	589
17	0.186	225	300	0.197	222	318	0.187	226	320
Arith. mean	0.207	175	—	0.204	177	—	0.212	174	—
Stand. dev.	0.030	30	—	0.041	31	—	0.027	29	—

The data shown in Tables I and II demonstrate rather conclusively that the moment method yields valid results. In Table I, the k values obtained by the moment method in no case differ from those obtained by the Reed-Theriault method by much more than 5 per cent. The values obtained for L, the total ultimate demand, are in even better agreement for the two methods. The term $\sum R^2$, which represents the sum of the squares of the deviations of the individual points from the theoretical curve given by the k and L values, is nearly identical for the two methods.

In Table II the disagreements between the Reed-Theriault and moment methods are somewhat greater in individual cases than those noted in Table I, but none of the five sets of k values differs by as much as 10 per cent. Deviations in the values of L are even smaller in magnitude, only one exceeding 3 per cent. The slope method, which is a least-squares treatment of the differences between successive B.O.D. measurements, yields k values (Table I) that are on the average slightly closer to the Reed-Theriault method than are those of the moment method. The slope method is the simplest of least-squares procedures and has the added virtue that it yields results that are not influenced by the existence of lag periods or high initial demands. If the data exhibit sizable lag periods, the Reed-Theriault and moment methods give incorrect evaluations of k and L. A modification of the moment method that takes

TABLE II.—Values of k and L for Industrial Wastes as Determined by Analysis of Data by Various Methods

Experimental Material	Reed-Theriault Method		Slope Method		Moment Method	
	k	L(p.p.m.)[1]	k	L(p.p.m.)[1]	k	L(p.p.m.)[1]
1. Sulfite pulp waste, 0.02%	0.152	4.89	0.151	4.99	0.151	4.90
2. Sulfite pulp waste, 0.02%	0.130	4.97	0.132	5.01	0.128	4.99
3. Sulfite pulp waste, 0.02%	0.135	5.07	0.137	5.14	0.125	5.16
4. Penicillin waste, 0.045%	0.132	5.54	0.148	5.42	0.121	5.72
5. Penicillin waste, 0.03%	0.118	3.99	0.146	3.67	0.109	4.11

[1] L values for the industrial wastes refer to the diluted material.

TABLE III.—Reliability of Moment Method by Replicate Tests

	Test No.					
	1		2		3	
	k	L	k	L	k	L
Values for random single bottles	0.219	170	0.202	140	0.227	207
	0.203	172	0.201	141	0.227	206
	0.217	170	0.205	140	0.242	201
	0.213	169	0.199	142	0.227	207
Means of singles	0.213	170	0.202	141	0.231	205
Standard deviations of singles	0.006	1.1	0.003	0.6	0.007	2.5
Values for random pairs of bottles	0.216	169	0.200	142	0.223	208
	0.209	171	0.201	141	0.237	203
Means of pairs	0.213	170	0.201	142	0.230	206
Standard deviations of pairs	0.004	1.0	0.0004	0.07	0.007	2.5
Values for means of four bottles	0.213	170	0.204	141	0.231	205

lag periods into account is presented in a succeeding section.

The reliability of the moment method can be tested in another manner—that is, by taking a series of B.O.D. data containing, for example, four replicate bottles for each time and comparing the k and L values computed from random single bottles and random pairs of bottles with those computed from the means of the four replicates. This is an exacting procedure, because it combines a test of the reliability of the method with a test of the precision of the data themselves. The test has been applied to three 7-day B.O.D. series, in each of which four bottles were titrated on each day. The results are shown in Table III.

The results of the replicate tests tend also to confirm the reliability of the moment method. They also show that in carefully done B.O.D. studies, little is gained in precision by going from two-bottle to four-bottle replicate tests.

Treatment of B.O.D. Data Containing a Lag Phase

In B.O.D. studies there sometimes appears evidence of a lag phase in the first part of the curve—that is, the oxygen demand does not proceed initially at its maximum rate. Many reasons for this behavior can be given; lack of adequate seeding is one of them. In other studies, the initial rate of B.O.D. is much higher than that manifested later. This type of curve exhibits what may be termed a negative lag. Such B.O.D. curves cannot be accurately formulated by the usual equation unless the lag phase is taken into account. The B.O.D. equation with lag phase may be written in either of the following forms:

$$y = L(1 - 10^{-k(t-t_0)}) \qquad (2a)$$

or

$$y = L(1 - C\ 10^{-kt}) \qquad (2b)$$

in which t_0 is the lag period and $C = 10^{kt_0}$. The slope method has been extended to permit evaluation of the lag (5), and the moment method can similarly be extended. As is the case with any statistical procedure, the addition of another variable increases the amount of computation necessary.

The procedure for analyzing by the moment method a set of B.O.D. data containing a lag phase is as follows:

1. Compute $\sum y$ and $\sum(ty)$ as previously described.

2. Compute the sum of the t values, $\sum t$.

3. Compute, also, t^2 and t^2y, and take the sum of the values of each quantity, $\sum t^2$ and $\sum(t^2y)$.

4. Compute the derived quantity: $\frac{\sum(ty)/\sum t - \sum y/n}{\sum(t^2y)/\sum t^2 - \sum y/n}$—in which n is the number of observations involved; that is, the observed points on the B.O.D. curve. This quantity permits the evaluation of k and ultimately of L

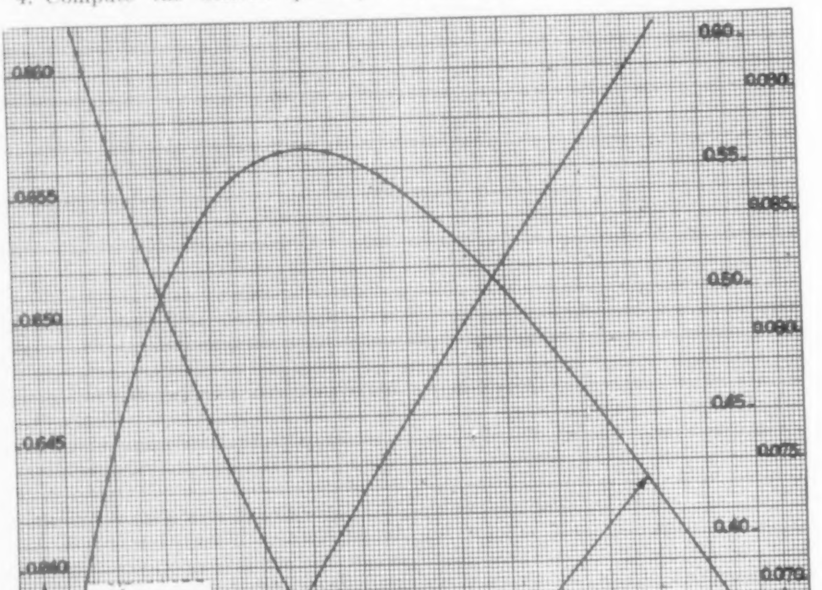


FIGURE 4.—Curves for B.O.D. computation with lag phase, based on 5-day time sequence.

and of t_0, the lag, from a previously prepared graph for the proper time sequence. Figure 4 is the appropriate graph for the time sequence 1, 2, 3, 4, 5 days.

In the following illustration, the initial rate of demand is abnormally high, producing a negative lag.

t (days)	B.O.D., y (p.p.m.)	ty	t^2	t^2y
1	76	76	1	76
2	99	198	4	396
3	125	375	9	1,125
4	144	576	16	2,304
5	155	775	25	3,875
15	599	2,000	55	7,776

Then

$$\sum y/n = 599/5 = 119.8000$$

$$\sum(ty)/\sum t = 2{,}000/15 = 133.3333$$

$$\sum(t^2y)/\sum t^2 = 7{,}776/55 = 141.3818$$

and

$$\frac{\sum(ty)/\sum t - \sum y/n}{\sum(t^2y)/\sum t^2 - \sum y/n} = \frac{133.3333 - 119.8000}{141.3818 - 119.8000} = 0.6271$$

Enter Figure 4 on the vertical axis labeled $\frac{\sum(ty)/\sum t - \sum y/n}{\sum(t^2y)/\sum t^2 - \sum y/n}$ with the value 0.6271, and proceed horizontally to the diagonal straight line. Extend a vertical line to the axis labeled k and read $k = 0.095$. Extend the vertical line to the curve labeled $\frac{\sum(ty)/\sum t - \sum y/n}{CL}$ (concave downward), and proceed horizontally from the intersection to the scale at the far right; read $\frac{\sum(ty)/\sum t - \sum y/n}{CL} = 0.0778$. Hence, $\frac{133.3333 - 119.8000}{0.0778} = CL$, and $CL = 173.9$. Continue the same vertical line to the curve labeled $\frac{L - \sum y/n}{CL}$, and read horizontally on the inside right-hand scale $\frac{L - \sum y/n}{CL} = 0.544$. Then $L = 0.544(173.9) + 119.8 = 214$ p.p.m.

Also, $C = \frac{CL}{L} = \frac{173.9}{214} = 0.812$ and t_0, the lag period, $= \frac{1}{k}\log_{10}C = \frac{1}{0.095}(-0.091) = -0.96$ day. The complete equation of the curve of best fit for the data is then

$$y = 214(1 - 10^{-0.095(t+0.96)}). \quad (3)$$

Mathematical Basis of Method

In considering a number of determinations, n, of B.O.D. at any specified times, t_1, t_2, t_3, etc., according to any desired sequence, the observed individual values, y_1, y_2, y_3, etc., of the B.O.D., can be matched against their corresponding theoretical values as derived from Eq. 1.

By equating the zeroth moments of the observed and theoretical values, the following expression is obtained:

$$\underset{\text{(Observed values)}}{\sum_{i=0}^{n} y_i} = \underset{\text{(Calculated values)}}{\sum_{i=0}^{n} L(1 - 10^{-kt_i})} \quad (4a)$$

Changing to the Napierian form* to simplify subsequent calculations,

$$\sum_{i=0}^{n} y_i = \sum_{i=0}^{n} L(1 - e^{-Kt_i}) \quad (4b)$$

in which $K = 2.3026\,k$.

Eq. 4b can be reduced to

$$\sum_{i=0}^{n} y_i = (n+1)L - L\sum_{i=0}^{n} e^{-Kt_i} \quad (4c)$$

Similarly, the first moments of the observed and theoretical values may be equated obtaining the following expression:

$$\sum_{i=0}^{n}(t_iy_i) = \sum_{i=0}^{n}(t_iy) = \sum_{i=0}^{n} L(1 - 10^{-kt_i})t_i \quad (5a)$$

* This transformation is optional. It allows the use of tables of exponentials for subsequent computations, but the same results can be obtained by computing the values of 10^{-kt} directly.

which can be transformed to

$$\sum_{i=0}^{n} (t_i y_i) = L \sum_{i=0}^{n} t_i - L \sum_{i=0}^{n} t_i e^{-Kt_i} \quad (5b)$$

If L is eliminated by dividing Eq. 4c by 5b,

$$\frac{\sum_{i=0}^{n} y_i}{\sum_{i=0}^{n} (t_i y_i)} = \frac{(n+1) - \sum_{i=0}^{n} e^{-Kt_i}}{\sum_{i=0}^{n} t_i - \sum_{i=0}^{n} (t_i e^{-Kt_i})} \quad (6)$$

Eq. 6 represents the heart of the method. The left-hand side is determined solely by the time sequence (values of t_i) of the observed data and by the observed values of B.O.D. (values of y_i) obtained at these times. The right-hand side is determined by the time sequence, the total number of observations, and the value of K, the rate constant of the B.O.D.

A time sequence can be chosen—for example, $t = 1, 2, 3, 4, 5, 6, 7$ days for which $n = 7$ and $\sum t_i = 28$—and Eq. 6 reduced to an equation in terms of the observed values and K, thus:

$$\frac{\sum y_i}{\sum (t_i y_i)} = \frac{8 - (e^{-K\cdot 0} + e^{-K\cdot 1} + e^{-K\cdot 2} \cdots + e^{-K\cdot 7})}{28 - (0e^{-K\cdot 0} + 1e^{-K\cdot 1} + 2e^{-K\cdot 2} \cdots + 7e^{-K\cdot 7})} \quad (7a)$$

or

$$\frac{\sum y_i}{\sum (t_i y_i)} = \frac{8 - (1 + e^{-K} + e^{-2K} \cdots + e^{-7K})}{28 - (e^{-K} + 2e^{-2K} \cdots + 7e^{-7K})} \quad (7b)$$

Assuming any values desired for K (and hence for k), it is a simple matter to evaluate the right-hand member of the equation, using a table of exponential functions. With enough values, a graph can be prepared of this right-hand term against the assumed values of k. This is the origin of the graph in Figure 3, which was employed in the example illustrating the method. Similar graphs can be prepared for any desired time sequence.

It remains only to develop an equation for determining L. This is done by returning to Eq. 4c, eliminating the term $t = 0$, $y = 0$, which gives

$$\sum_{i=1}^{n} y_i = nL - L \sum_{i=1}^{n} e^{-Kt_i} \quad (8)$$

Dividing Eq. 8 by nL gives

$$\frac{\sum_{i=1}^{n} y_i}{nL} = 1 - \frac{1}{n} \sum_{i=1}^{n} e^{-Kt_i} \quad (9)$$

Eq. 9 contains only known terms, except for L. For example, for the series $t = 1, 2, 3, 4, 5, 6, 7$ days, it becomes

$$\frac{\sum y}{7L} =$$

$$1 - \frac{1}{7} (e^{-K} + e^{-2K} + \cdots e^{-7K}) \quad (10)$$

Evaluating the right-hand side of Eq. 10 by assuming values of K, it is possible to plot the second curve in Figure 3, which is a graph of the term $\frac{\sum y}{L}$ against k. This is used to obtain the value of L once the value of k has been determined, as shown in the example. Similar pairs of curves for other time series can easily be prepared, and two others are included in Figures 1 and 2.

The mathematical development of the theory and graphs for the method with lag phase is omitted in the interest of brevity, but will be made available by the authors to those workers who desire it.

Summary and Conclusions

A simplified method has been presented for determining the rate constant, k, and the ultimate biochemical oxygen demand, L, from any set of B.O.D. observations. The method entails a minimum of arithmetical calculation and permits evaluation of k and L in a much shorter time than any previous method. It requires only that observations be made at some

previously selected sequence of time intervals for which the necessary graphs have been prepared. The authors have included in this paper graphs for a few time sequences believed to be useful, but will be glad to assist other workers in preparing graphs for any other sequences that may be desired.

References

1. Reed, L. J., and Theriault, E. J., "The Statistical Treatment of Velocity Data." *Jour. Phys. Chem.*, **35**, 673 (1931); **35**, 950 (1931).
2. Fair, G. M., "The 'Log-Difference' Method of Estimating the Constants of the First-Stage Biochemical Oxygen Demand Curve." *Sewage Works Jour.*, **8**, 3, 430 (May, 1936).
3. Thomas, H. A., Jr., "The 'Slope' Method of Evaluating the Constants of the First-Stage Biochemical Oxygen Demand Curve." *Sewage Works Jour.*, **9**, 3, 425 (May, 1937).
4. Snow, W. B., "Biochemical Oxygen Demands of Chlorinated Sewage." Doctoral thesis, Harvard Univ. (1948).
5. Thomas, H. A., Jr., "Analysis of the Biochemical Oxygen Demand Curve." *Sewage Works Jour.*, **12**, 3, 504 (May, 1940).
6. "Standard Methods for the Examination of Water and Sewage." 9th Edition. Amer. Pub. Health Assn. (1946).

DISCUSSION

By C. C. Ruchhoft

Chief, Physics and Chemistry Section, Research and Development Branch, Environmental Health Center, U. S. Public Health Service, Cincinnati, Ohio

Since 1936, the Sanitary Engineering group at Harvard University, under the leadership of Dean Gordon M. Fair, has presented a series of constantly improved methods for deriving the constants for the unimolecular curves of best fit for B.O.D. data. The present paper by Moore *et al.* carries this progress forward another step. The derivation of the oxidation rate constant, k, and the apparent L-value for the unimolecular curve has now been simplified so that any one with a knowledge of simple arithmetic and provided with the proper charts may easily determine these parameters of the equation that fits his data.

The "moment method" appears to actually require less labor than any of the graphical methods of approximating k and L which have been popular because of their simplicity. In addition, the moment method has the advantage of being a definite procedure requiring no discretionary decision on the part of the user. In the application of graphical procedures, there are frequently a number of combinations of k and L which will give a fair fit of the data. This may lead an honest observer to select or test values most compatible with his views and lead to erroneous conclusions.

The Thomas "slope method" (1) has been used extensively over a long period in the Cincinnati laboratory. A few years ago, the laboratory developed modified formulas, which greatly shorten the work of calculation for the slope method when continuous observations at equal intervals are available. These formulas are as follows:

$$y' = \frac{y_L + y_{L-1} - y_0 - y_1}{2\,\Delta t} \qquad (1)$$

$$\text{and } y\,y' = \frac{y_L\,y_{L-1} - y_0 y_1}{2\,\Delta t} \qquad (2)$$

in which y_L is the B.O.D. of the last observation in the series, y_{L-1} is the B.O.D. of the second last observation, y_0 is the initial B.O.D. observation (zero, unless the calculation is started at other than $t = 0$), y_1 is the first B.O.D. observation after y_0, and Δt is the time interval between observations (usually one day).

These two formulas permit obtaining

the summations of y' and $y\,y'$ directly, without the calculations that are necessary in the example given by Thomas (2). The summation of the B.O.D. observations, y, the y^2 summation for the series, and the summation values for y' and $y\,y'$ obtained with Eqs. 1 and 2 are then simply substituted in the two simultaneous equations (3) and solved. The Thomas slope method, with the application of Eqs. 1 and 2 to simplify the calculation, has been used in the Cincinnati laboratory for a number of years and has proven very satisfactory. Most of the observations are made continuously at equal intervals. Thus, the time-saving formulas (Eqs. 1 and 2) have been very useful.

The calculation of the lag factors, as embodied in either the modified slope method or the present moment method, has never seemed to be worthwhile in this work. The positive lag is a real thing, especially when low-temperature B.O.D. observations are made. Under such circumstances, it is preferred simply to examine the data and apply the calculation to the data after recovery from lag is indicated. Data embodying such technique have already been published (4).

The phenomenon referred to by the authors as "negative lag" is an entirely different situation resulting from other causes. However, it serves to illustrate the fact that there are various possible patterns of biochemical oxidation in water and that these do not all fit the unimolecular equation.

It should be understood that there is nothing fundamental about the unimolecular equation in relation to biochemical oxygen demand satisfaction. The application of the equation to B.O.D. data is empirical in nature. Its success in this fitting is essentially due to the tremendous flexibility of this exponential equation. This equation, when it applies, has very definite advantages: (1) It is dimensional; (2) It permits the description of the rate of change as represented by a B.O.D. series to be indicated by a single value, k; and (3) It fixes an apparent limit for the so-called ultimate demand. This ultimate demand appears to be entirely theoretical, but it is useful for comparative purposes. Although the equation has been developed on various pseudo-theoretical grounds, in connection with B.O.D. observations, there is no simple basic factor upon which the general nature of the course of such observations can be explained. It is believed, therefore, that such a mathematical sophistication as the negative lag has little value of either a practical or theoretical nature. It is, however, a good example of mathematical perfectionism.

The course of biological oxidation in dilute solutions is determined by factors that are by no means simple. It represents the results of the growth and metabolism of a complex and dynamic microbiological system on a substrate of varying complexity. Factors which may be expected to affect the course of the oxidation include:

1. The numbers and complexity of the microflora and microfauna.
2. The concentration and complexity of the organic constituents in the substrate.
3. The presence of the necessary mineral accessory nutrients.
4. The pH and buffering capacity of the substrate.
5. The presence of toxic or enzyme de-activating compounds.
6. The temperature.
7. The presence of dissolved oxygen or other hydrogen acceptors.

Although most of these factors are fairly well controlled in studies of biochemical oxidations, very little control is maintained over the biological system or seed. Further progress in understanding the basic causes for variations in biological oxidations may be expected as a result of several different types of studies now in progress. At the Environmental Health Center, the

dissipation of particular food components in complex substrates by a complex flora are being studied. At the Massachusetts Institute of Technology, Sawyer and Tom are making intensive studies on the effect of the nature and quality of seeding material on the course of biological oxidation. At Rutgers University, members of Dr. Rudolfs' staff are applying the direct oxygen utilization method, which permits the study of concentrated wastes, to problems associated with the oxidation of sewage and industrial wastes. At the Illinois State Water Survey, Buswell and his associates are continuing on studies of factors involved in the nitrification phase of biochemical oxidations. Another attack is being followed at the University of Wisconsin, where Nichols and Zehnpfennig are investigating the oxidation of substrates by controlled microflora.

The moment method should simplify the analysis of the data obtained in these and other B.O.D. studies. Before the moment method can be useful generally, there is need for the preparation of a wider variety of moment charts than are shown in Figures 1 to 4. The Harvard group, or some other organization, could perform a real service by preparing the necessary charts required for the indicated calculations with other common combinations of observations which may be used. When the appropriate charts become generally available, the moment method should prove to be an extremely useful tool to all those interested in stream investigations or research studies on biochemical oxidation patterns.

References

1. Thomas, H. A., Jr., "The 'Slope' Method of Evaluating the Constants of the First-Stage Biochemical Oxygen Demand Curve." *Sewage Works Jour.*, **9**, 3, 425 (May, 1937).
2. Ibid., p. 427.
3. Ibid., p. 428.
4. Ruchhoft, C. C., Placak, O. R., and Ettinger, M. B., "Correction of B.O.D. Velocity Constants for Nitrification." *Sewage Works Jour.*, **20**, 5, 832 (Sept., 1948).

CORRECTION

In the paper on "Simplified Dissolved Oxygen Computations" (THIS JOURNAL; Aug., 1950), a key sentence was inadvertently deleted in the course of editing. The sentence:

"It will be noted that Eq. 6b takes the form of a straight line ($y = m\,x + b$) if $1/Q$ is used in place of Q as abscissa (x)."

should be inserted on page 1057 following the words "(Figure 2)" in the fifth line below Eq. 6b.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

SAFETY IN ONE-MAN OPERATION

Elsewhere in this issue of the Corner is contained a suggestion that in one-man treatment plants, the operator be required to call the local police department every hour. Obviously, this will bring forth strident objections from both the operator, who has other things to do, and the police, who are not particularly interested in taking on another "watchdog" job.

Calm reflection on the matter, however, will indicate that such a scheme has merit in many of the situations specifically referred to—plants where one man is on duty alone. Despite all precautions to the contrary, things sometimes do go wrong. A bad fall, a chlorine leak, or any of a number of other hazards, may mean that a lone operator can get into serious—even fatal—difficulty. The possibilities are even more appalling when it is remembered that most sewage treatment plants are situated in isolated sections of the community, thereby reducing almost to the vanishing point the prospect of chance aid in case of need.

Provision of some definite checking arrangement, particularly with an agency that is trained and equipped to give emergency aid of the types likely to arise, certainly deserves more than passing attention. A good case in point is one out of our own experience, where the one-man night shift at an old, out-moded sewage treatment plant was thought to be in danger because of his heavy work load and the hazardous condition of the equipment. It was the old, old story of "patch and keep going." Not four months after half-hourly contact with the police department was made a necessary part of his routine, this same operator had his life saved by a cruiser-car crew sent to investigate when he hadn't called in. A chlorine leak, plus a fall on the slippery floor occasioned thereby, surely would have "done him in" without the timely aid.

In line with this same reasoning, thought also should be given to assignment of hazardous routine duties to the night man working alone. At one plant we know of, it had been the practice for years for the single night operator to skim the rectangular primary tanks (actually Imhoff tanks) by hand soon after daylight—long before the day crew arrived. Not until state authorities suggested guard rails around these same tanks was the danger fully realized. The guard rails, however, would have seriously hampered the skimming operation. As a compromise solution to the problem, skimming of the tanks is now being done by a day-shift operator, who at least has someone else handy in case of need. Not an ideal arrangement, true, but at least one that does not ask for more trouble than is necessary.

Simple things can cause mishaps. How many times have you heard the statement: "I knew that, but just didn't think of it."? The time to think about the hazards is before they grow up and become accidents. A little advance planning may be all that's needed to avert a casualty.

H. P. O.

PRIMARY DEVICES AND METERS FOR WASTE FLOW MEASUREMENTS *

By Howard O. Hite

Engineer, Brown Instruments Division, Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

Flow meters for waste measurement fall into two categories. The first class, differential head meters, is used for measurement in completely filled pipes and includes such primary devices as orifice plates, nozzles, and venturi tubes and a suitable differential pressure meter. The second category, known as head-area meters, is used for measurement of flow in open channels and partially filled pipes. Examples of this type meter are weirs and Parshall flumes.

As complete coverage of the subject would be exceedingly lengthy, this paper merely points out the advantages and limitations of each of the most commonly used devices as an aid in the selection of meters for specific applications.

Differential Head Devices

The differential head meter, as previously mentioned, requires that the pipe be kept filled with fluid for satisfactory operation. All primary devices for use with such meters are basically differential pressure producing resistances. As the fluid enters the resistance, the velocity is increased, with a loss in static pressure. It is this drop in static pressure that is measured as an indication of flow.

Venturi Tube

The venturi tube (Figure 1) is the oldest of the modern primary elements. The designs used today are essentially the same as those used by Clemens Hershel in 1887. The venturi tube consists of a conical reducing section, a cylindrical throat section, and a diverging exit cone. The transitions from the entrance cone into the straight throat are rounded off by an easy tangential curve to avoid the resistance caused by a sharp corner and also preclude the possibility of cavitation. The differential pressure is measured between taps located slightly upstream of the entrance cone and at the throat.

When the venturi is used with clean fluids, a piezometer ring is usually used at both of these points to obtain the average static pressure at each point of measurement. For many sewage and industrial waste applications the piezometer rings are replaced by a single tap at each measurement point. With this arrangement, clear liquid purges may be used to keep the taps open. An alternate scheme, which is often used, is a manually operated cleaning valve.

The entrance cone generally has an included angle of 21° and the exit cone an included angle of 7°. This design gives the optimum pressure recovery. Usually about 80 to 90 per cent of the pressure drop at the throat is regained. Other angles have been used to reduce the length and weight of tubes, but this is done at a slight reduction of the pressure recovery characteristics.

Cast iron is the most common metal used for venturi tubes. However, special tubes of other materials may be obtained to overcome corrosion problems. Brass, bronze, stainless steel, concrete, and even rubber-lined tubes have been supplied.

The venturi tube has the following advantages over other differential devices:

1. Tapered approach and exit cones give lowest pressure loss.
2. For the same head differential and diameter, flow rates will be approximately 50 per cent higher than for an orifice.

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28–30, 1950.

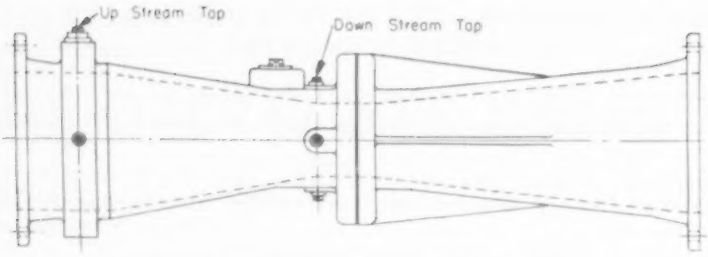


FIGURE 1.—Schematic diagram of venturi tube.

3. There are no pockets where suspended particles in the solution may accumulate.

4. Long runs or straight pipe are not required.

The principal limitations of a venturi are its relatively high cost, large size, and lack of flexibility of range.

Flow Nozzle

The flow nozzle (Figure 2) consists essentially of the entrance cone and throat section of the venturi, but has no recovery or exit cone. The upstream or high-pressure tap is made through the pipe wall at approximately one pipe diameter from the entrance. The low-pressure or downstream tap is located at the point of smallest jet area. The nozzle, which can be manufactured from most any material, has the following advantages:

1. It can measure 50 per cent more flow than an orifice.

2. Shorter meter runs are permissible than for an orifice.

3. It can be simply installed between pipe flanges.

The disadvantages are:

1. Although its cost is below that of a venturi, it is still much higher than that of an orifice.

2. Experimental work remains to be done in order to determine complete coefficients.

3. Not suitable for liquids containing solids in suspension.

Orifice

The orifice is probably the oldest device for measuring or regulating fluid flow. Records show that it was used to measure flow to householders in Rome during Caesar's time. Nevertheless, it did not receive real recognition as a commercial primary element until about the time of World War I.

The most common type of orifice is

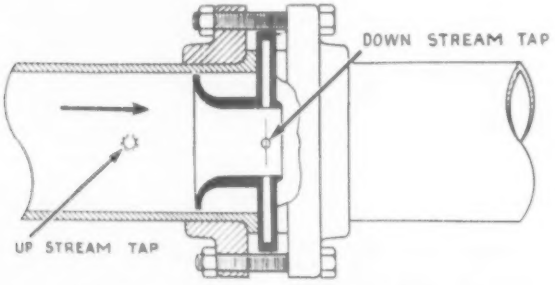


FIGURE 2.—Schematic diagram of flow nozzle.

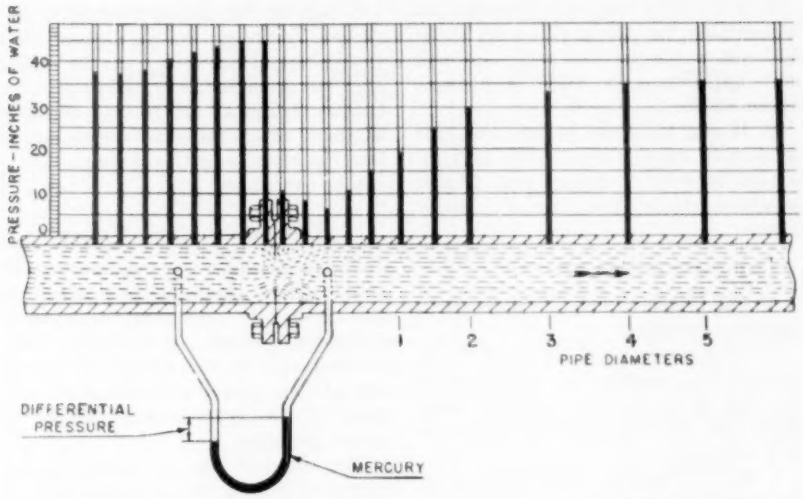


FIGURE 3.—Pressure characteristics at a concentric orifice in a pipeline.

the concentric orifice. It consists of a thin flat plate with a round hole, mounted between standard pipe flanges so that the hole is concentric with the pipe.

The Fluid Meters Committee of the American Society of Mechanical Engineers has spent considerable time and money studying the characteristics of flow through thin plate orifices. With the data obtained, orifice plates can be calculated and installed to measure flow with accuracy equal to that of the best venturi tubes. Orifice plates are usually made of stainless steel, although other materials such as glass and monel metal have been used.

Figure 3 shows the pressure characteristics at the orifice. The pressure builds up slightly in front of the orifice, then drops suddenly on downstream side and continues to drop for a short distance along the pipe before the recovery starts. The point of minimum pressure and, incidentally, maximum velocity, is known as the vena contracta. It can be seen that the points at which the differential pressure measurements are taken are critical. For this reason, the Fluid Meters Committee has established orifice coefficients for the three standard pressure tap locations. These are known as flange taps, vena contracta taps, and pipe taps.

Flange taps are, as the name implies, made in the orifice flanges. They are spaced 1 in. upstream and downstream from the orifice. Standard tapped flanges are available and are simpler to install than the other two types, as no drilling and tapping of the pipeline is required.

Vena contracta taps are made with the upstream tap 1.0 pipe diameter from the orifice and the downstream tap at the vena contracta, usually about 0.5 pipe diameter from the orifice. These are not quite as easy to install, but are slightly more accurate than flange taps.

Pipe taps utilize only the permanent pressure loss. Therefore, the differential pressure will be considerably less for a given flow than with flange or vena contracta taps. Pipe taps are located 2.5 pipe diameters upstream and 8 pipe diameters downstream from the orifice.

The orifice has the following advantages:

1. The cost is low. For example, an orifice plate for a 6-in. line costs about $17. A nozzle for the same line will cost approximately $135; a venturi, about $375.

2. It can be made in any machine shop with conventional tools and installed between standard pipe flanges available from any piping supply house.

The disadvantages are:

1. The pressure loss is higher than that of a venturi.

2. Flow capacity is less than for a venturi or a nozzle; the exception to the rule is in the case of pipe taps, where the flow capacity is comparable to a venturi.

3. It is not suitable for liquids carrying solids in suspension.

4. Long pipelines are required in front of the orifice.

Work is now being carried on by the Fluid Meters Committee to determine coefficients for segmental and eccentric orifices (Figure 4). In these orifices the opening is placed tangent to the bottom of the pipe. When these data become available the limitations regarding measurement of suspended solids with the orifice plate should be removed.

Figure 5 shows a comparison of the principal application considerations for each of the primary elements discussed. Although it may appear that the principal advantage of the orifice over the other forms is its low cost, by proper design of orifice and selection of meter range the other objections of lower capacity and higher pressure loss can be overcome.

Differential Head Meters

All of the meters for measurement of flow through these primary elements are primarily differential pressure measuring devices. As such, they must contend with the fact that flow through any of these primary devices is proportional to the square root of the differential pressure.

The simplest type of secondary instrument is a variation of the common mercury manometer. A typical meter of this type is shown in Figure 6. It consists of a float chamber, a range tube, and a connecting **U**-tube. The differential pressure created by the primary element is connected to the float chamber and range tube. In this design the float chamber is the high-pressure side of the manometer. This is not necessarily the case in all meters of this type.

As the differential pressure increases, the mercury level falls in the float chamber and rises in the range tube, causing the float to rotate a shaft in a

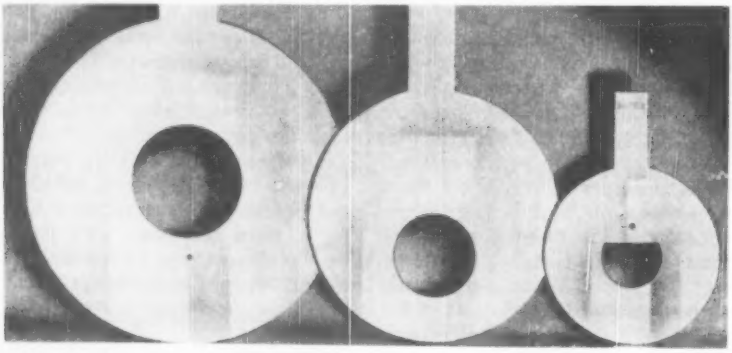


FIGURE 4.—Types of pipeline metering plates now under study, including concentric, eccentric, and segmental orifices.

COMPARISON OF DIFFERENTIAL HEAD TYPE PRIMARY ELEMENTS			
PROPERTY	CONCENTRIC ORIFICE	VENTURI	NOZZLE
Accuracy	Excellent	Excellent	Good
Cost	Excellent	Poor	Fair
Pressure Loss	Poor	Good	Poor
Suitability for Solids in Suspension	Poor	Good	Fair
Range Changing Ease	Excellent	Poor	Poor
Capacity for a Given Line Size	Good	Excellent	Excellent
Length of Straight Pipe Required	Poor	Excellent	Excellent

FIGURE 5.

pressure-tight bearing. This shaft moves the pen or pointer. Range tubes are made in an interchangeable series, so that the range of the instrument may be changed by merely replacing the range tube. This type meter has square-root charts and scales.

Other types of secondary instruments use cams, shaped range tubes, shaped bells, or other mechanical and electrical means to extract the square-root function and use uniformly graduated charts. Square-root charts give best readability and accuracy at the high end of the scale, whereas linear charts have improved readability at the low end. The choice of chart is primarily a matter of personal preference.

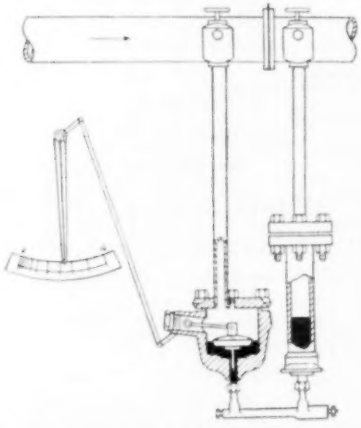


FIGURE 6.—Simple differential pressure flow meter.

Secondary meters are available in a wide variety of forms. These include electric and pneumatic transmission, or direct-connected instruments. Indicating, recording, integrating, and controlling instruments can be obtained for almost any combination of these functions.

In specifying instruments for a given application, the meter manufacturer will insist on knowing all the conditions involved. If the application requires special consideration with respect to corrosion, head loss, or solids in suspension, he will advise the best form of primary element and meter for the particular application.

Head-Area Devices

In head-area meters, both the cross-sectional area of the stream and the head are variables, but not independently of each other; the area is a function of head. These meters are limited to measurement of liquid flow in open channels.

Parshall Flume

The most widely used primary device of the head-area meter type for sewage and industrial wastes is the Parshall flume (Figure 7). It consists of an entrance section with converging walls and level floor, a throat section with parallel walls and downstream sloping floor, and an exit section with diverging walls and a rising floor. If the flume is properly installed in a channel, the rate of flow through the flume can be determined by a single measurement of the head or level made at a point one-third of the length of the inlet section from the entrance. A stilling well should be provided at the point of measurement to permit more accurate reading of the head.

The Parshall flume has the following advantages over weirs or other head-area meters:

1. It is easy to construct and may be made in a variety of materials (wood, sheet metal, or poured concrete).
2. Solids in suspension are readily carried through the flume and do not affect the measurement accuracy.
3. Wide variations in capacity are possible. Flumes have been made with throat sections as small as 3 in. and as large as 50 ft.
4. The loss of head required for flow measurement is extremely small.

The only disadvantage of the Parshall flume is that its accuracy is not as high as that of a well-made and

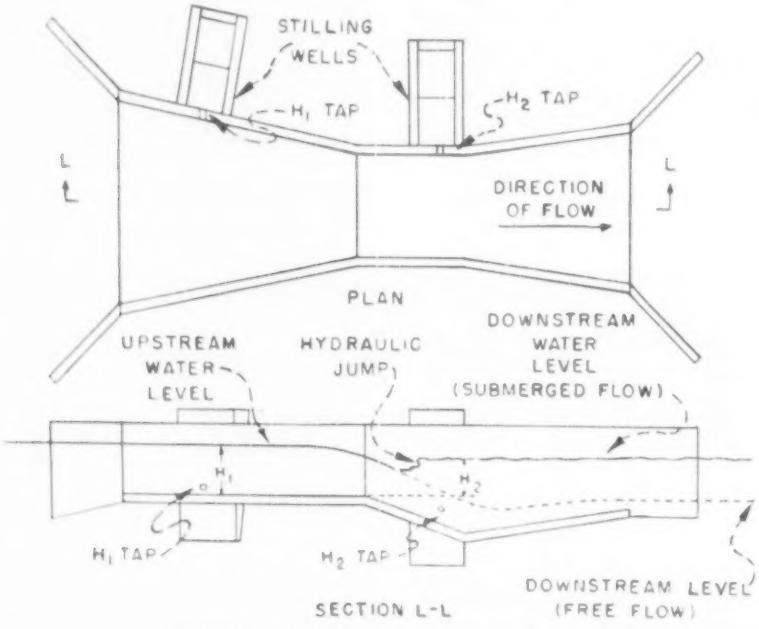


FIGURE 7.—Basic elements of Parshall flume.

properly installed weir. Accuracy is generally stated to be within 2 to 5 per cent.

Weirs

A weir is a dam in a stream with a notch cut in the crest. The most common notches are rectangular, triangular, and a combination of the two, trapezoidal. Rectangular weirs generally are used for large flows where the variations between maximum and minimum flow are not too wide. The triangular weir is used for accurate measurement of small rates of flow and is particularly sensitive to changes in rate of flow at the low end of its range. The trapezoidal, or Cipolletti weir combines the features of both, having wider range ability than either.

Although the weir is the most accurate of the head-area meters, it has several limitations as a primary element for industrial use:

1. It requires construction of a weir box to obtain the proper flow approach to the weir.
2. Sediment in the fluid will settle in the weir box, with adverse effects on the weir calibration.
3. The loss of head through the weir will be equal to the head measured.

Kennison Nozzle and Parabolic Flume

Two other head-area devices in use today are the Kennison nozzle and the parabolic flume. They are both suitable for measurements of fluids containing solids in suspension. Like weirs, however, they must operate with a high loss of head compared to the Parshall flume.

Head-Area Meters

The measuring devices used for head-area meters are generally float actuated. Motion of a float riding on the liquid surface in the stilling well is transmitted to the instrument by a cable or tape. The instrument usually incorporates a cam or other device that extracts the proper function to give a uniform flow scale. These instruments are also available in the recording, indicating, and integrating forms of the differential head meters.

Summary

This paper has presented but a brief glimpse of the principal primary devices and meters for waste flow measurement. It is hoped, however, that it has pointed out the wide variety of meters from which to choose, and explained some of the reasons for having so many types available.

THE DAILY LOG

Marion, Indiana

By David P. Backmeyer, *Superintendent*

March 5—Received a new impeller for the 4,000-g.p.m. sewage pump, which is gas engine driven. The old one will be outfitted with new wearing rings and kept as a spare. This was the original pump impeller; it had handled 5,902 m.g. of raw sewage. The 20-in. gate valve on the suction side of the pump was a most interesting piece of equipment to dismantle (it would not operate until it was dismantled). The valve housing proved to be an excellent storage place for such items as nails, paper clips, wood screws, metal screws, razor blades, bottle openers, keys, bus fare tokens, metal washers, curtain clips, rifle bullets, general sewage mineral grit, and even a couple of U. S. copper coins. The efficiency of the pump increased about 15 per cent with the installation of the new impeller, which has a stainless steel wearing ring working inside the bronze casing ring.

March 9—Local electricians completed the installation of new service lines to all inside and outside power units that were formerly fed by underground, lead sheathed cable. Failure was due to moisture, which penetrated the lead protective coating. Replacements were made by using exposed metal conduit wherever possible; no lead sheathed wire was used.

March 10—Our front yard was given its first haircut of the spring. The dark-green, almost purple color is something to marvel at this year. The plant tank trucks gave this area a thorough drenching with digested liquid sludge last December. The net result is a beautiful lawn, combined with an almost endless maintenance job in trying to keep it cut during the wet spring months.

March 12—We got some peculiarly colored sewage this afternoon. Upon checking in one area of the city, we found the City Water Department was opening fire hydrants in the annual main flushing program. The resultant coffee-colored water flowed to our sewers at about 1,000 g.p.m. while this work was underway. The discolorization was due to the iron in the well-water supply, which oxidized and settled out in the water mains. Some of the wells contain as much as 3.0 p.p.m. iron.

March 14—Our stone quarry lake (see Figure 1), about two-thirds of an acre in area, is loaded with its first algae bloom of the spring. The water looks like thickened green paint. Dissolved oxygen tests made on this water indicate these plants are adding considerable quantities of pure oxygen to the upper strata of the pond. The water contains considerable nitrogen as a result of the discharge of sewage plant effluent into the lake on various occasions. Samples taken at lower

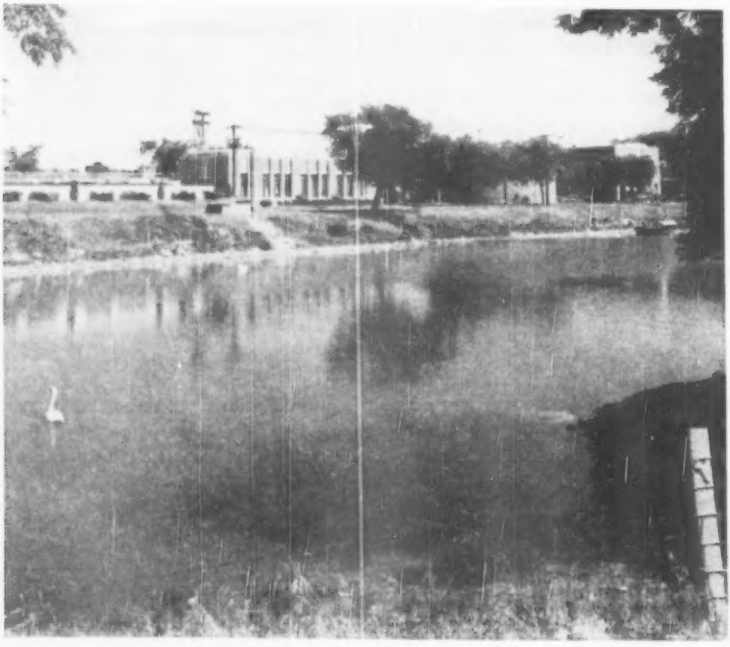


FIGURE 1.—Lake in abandoned quarry enhances beauty of Marion, Ind., sewage treatment plant.

depths do not show supersaturated concentrations of dissolved oxygen. An around-the-clock sampling and analysis survey also verifies the well-known fact that "old man" sunshine plays an important part in the activity of the algal growths.

March 15—Construction of a new fence is underway for conservation of the ducks and swans at the quarry lake. The fence posts are cedar and are all set in concrete. Common 26-in. hog fence with two strands of barbed wire on top should encourage our livestock to stay at home. At a $125 per pair cost for swans, we don't like to see these birds take off for the nearby river and forget to return home. On such occasions the local citizenry keeps our phone buzzing to let us know that our prized fowl are in the immediate neighborhood.

March 16—Considerable trouble is encountered with the incandescent lamps serving as night lights (continuous night operation circuit) in the compressor building. The relatively short life of these lamps is attributed to the vibrations in this building caused by the operation of the gas engines and blowers. Two new lamps of mercury vapor type are installed to replace four of the original fixtures. We now have some rather weird color combinations on the equipment in this building. The tile-red foundation blocks acquire a faded maroon color, and the blue trim on the gray enameled equipment is no longer very attractive. These undesirable features will be tolerated if the service of the new lamps proves to be satisfactory.

March 23—A severe downdraft condition in the stack of the gas-fired heating boiler has resulted in discharge of foul odors to the office and adjacent rooms in the service building. Installation of an H-type anti-downdraft gadget on top of the chimney has not cured the situation. The condition was more pronounced on cold, windy days when the stack temperature was lowered, and apparently the flue gases of the boiler could not raise this temperature. As a result of an inspection made by a local heating plant engineer, we ordered and installed a positive motor-driven fan directly in the furnace pipe at the entrance to the brick chimney. The blower requires 0.5 hp. for its operation, but the added operation cost for power will be a minor investment in the light of solving this perplexing problem. The unit also affords an additional positive means of ventilation for our large basement room, which houses most of the sewage gas control equipment. Excessive discharge velocities of flue gases from the boiler are prevented by the regulation of a conventional damper in the boiler stack, thereby permitting efficient utilization of the sewage gas fuel in the heating unit.

April 7—A local wire processing plant filed a request for special consideration on sewage disposal rates for the large volumes of uncontaminated cooling water they were forced to discharge to the sanitary sewer system (there was no separate storm relief sewer available at the factory site). They were advised to make a technical presentation of their case to the Board of Works, pointing out specifically what reductions in treatment costs might be realized by the city in handling this type of waste water at the treatment plant. The company complied by submitting a report prepared by a reputable engineer, who had had several years of experience as manager of a large municipal treatment works. This report was so convincing that a temporary discount agreement was granted to the industry. The final solution to the problem was accomplished by the industry when it installed disposal facilities for this water on its own property.

April 8—Our overloaded digestion system has been producing very little good-quality supernatant liquor. We classify good supernatant as that having a total solids content of less than 3,000 p.p.m. A digester tank opera-

tion program was outlined that enabled us to take the secondary digester out of service for such length of time as will permit the withdrawal of good quality liquor. This period proved to be 10 days, during which time nothing was pumped into or withdrawn from the tank. This is additional proof that we do need additional digestion capacity. Our so-called digested sludge thins out to a total solids content of 2.9 per cent during the heavy-load season. We have complete plans for the construction of additional digestion capacity, but we do not have the necessary dollars at present to proceed with the project.

April 11—We begin our annual air diffuser tube cleaning program for this spring. We plan to get this job completed before the added summer load might prevent the completion of this work, which usually takes about six weeks. Individual tanks are successively taken out of service while the carborundum tubes are removed from the headers and cleaned. There are 126 tubes in each of the four tanks, and each one is washed in detergent solution, soaked in chromic acid for 3 hr., thoroughly rinsed, and then remounted on the header. A special time-saving gadget has been built for dunking 60 of the tubes in the acid solution at one time (see Figure 2). The basket is fabricated to our specs and is made of acid-resistant stainless steel. The acid-storage tank is a reclaimed, rubber-lined tank that was formerly part of the vacuum filtration ferric chloride solution equipment. An electric hoist is used to facilitate the dunking process.

April 15—The 2-in. feeder lines in the aeration tank feed channels, which supply air to the plate diffusers in these channels, will have to be replaced. Corrosion again takes its toll! The replacements were made of galvanized wrought iron that was carefully cleaned and painted with rubber-base enamel prior to and after installation. The failures of the original galvanized pipe were principally at the threaded ends, where there was no protection over the exposed cut surfaces. Any future installation would certainly call for a switch to copper pipe with soldered joints in preference to the threaded fittings.

April 17—One of the liquid sludge tank trucks became stuck in a snow-covered field while unloading digested sludge. Two garbage department trucks were sent to the rescue; both of these also got into some unforeseen soft spots, and failed to return to the plant. Final rescue was made by a hired wrecker unit from a local garage. There's very little profit for the sewage treatment plant in this type of operation.

April 19—The rat population is getting pretty frisky, if the recent reports of our night operators are to be taken seriously. Some consideration has been given to the development of a cat population to combat the rat menace. It is doubtful whether an ordinary cat could handle some of the monsters that have been lurking around the grit removal truck. We resort to our old standby—the freshly prepared red squill as furnished us by our County Agricultural Agent. This mixture must be stored under refrigeration, as it contains fish and beef as the attractive ingredients for Mr. Rodent. We can always depend on him taking a goodly portion for his first and final banquet.

April 25—Prolonged rains have resulted in another high river stage. Raw sewage entering the plant is mostly river water. Sewage gas production is only about 15 per cent of normal as a result of almost complete loss of sewage solids to the stream. By completely closing the sluice gate at the head of the plant, all the flow from the main interceptor can be diverted to the river. This affords an opportunity to inspect the raw sewage wet well when it is completely pumped down. Any grit accumulations are shoveled to spots where they will be

FIGURE 2.—Plant-designed tank and accessories for cleaning 60 air diffuser tubes at one time.

picked up by the pump suctions when the flow is turned back into the plant.

May 13—We used the plant boat and a borrowed outboard motor to distribute 15 lb. of copper sulfate in the quarry lake. This dosage is calculated to kill the algal growths and not harm the fish life. The treatment is effective for only a few weeks. It must then be repeated to kill the new growth that usually reappears. Our 6-weeks old goat, the latest addition to our plant menagerie, takes a sun bath this afternoon with the three swans and the four muscovy ducks. This doesn't help the writer's rather serious case of spring fever.

May 24—The quarry lake is clear. Thousands of fingerling are easily seen from the shoreline as they literally swarm to the surface to fight for the bread scraps that are saved from the garbage and fed daily to the fish. Some of the schools of young catfish resemble a hive of bees as they move about in the water. If they all grow up to be big ones, there should be tons of good fishing for the local anglers.

SLUDGE UTILIZATION AT GREENWICH, CONN.*

By R. J. Kent

Sewage Works Engineer, Dept. of Public Works, Greenwich, Conn.

The Town of Greenwich, Conn., operates three small and one fair-sized primary sewage treatment plants. Two of the plants have heated sludge digesters; the other two digest sludge in unheated modified septic tanks. The four plants together produce an average of 22,000 cu. ft. of sludge each year. In 1949, for example, a total of 21,450 cu. ft. of air dried sludge was produced; at 30 lb. per cu. ft., this is a total of 330 tons.

At each plant, digested sludge is pumped to sand drying beds, air dried, and then removed by hand. At the plants the operators estimate the thickness of the dried sludge as it comes off the beds. As the area of each bed is known, it is an easy matter to compute the volume of sludge removed. The dried sludge is ground in shredders and stored on concrete platforms. It is estimated that approximately 90 per cent of the dried sludge is collected and used by the Greenwich park department, the remainder being used by private individuals, who usually carry a few bushels away in their cars. The sewer department has never publicized the use of its sludge, but a large quantity of sludge can be disposed of to individuals and local nurserymen. The sludge is free to all town residents, but they must cart it away.

Park Department Use

When a few truck loads of ground sludge have accumulated, the park department is notified and the sludge is hauled away. Formerly, the sludge was loaded onto the trucks by hand, but in 1949 the park department purchased a bucket loader attachment for a small tractor at a cost of about $400. The trucks are now loaded mechanically at a considerable saving in time and labor. Unfortunately, the peak period of sludge production corresponds to the park department's busiest season, but by giving advance notification the sludge usually can be picked up within a few days after grinding is finished.

The park department stock piles the sludge at various points and covers the piles with commercial superphosphate fertilizer. The amount used is not fixed, as the sludge is merely covered with what is thought to be enough superphosphate and left to age.

The sludge is used in a variety of ways. The major uses are: (1) compost, (2) over-all cover for grassed areas, and (3) mixed with soil for use with plants, trees, and shrubs.

In using the sludge in compost, the sludge from the storage piles is mixed with leaves, grass cuttings, and garden refuse. The whole pile is turned over a few times and then allowed to rot. The compost is then used for seedlings, flowers, and as a top dressing around shrubs and flowers.

After being reground, sludge from the storage piles is spread over the grassed areas maintained by the park department in the late fall and winter. The sludge was formerly spread by hand, but now a sand spreader attachment on the rear of one of the trucks is used. This sand spreader is similar to that used by highway departments to spread sand over icy roads. This method is reported to be much better than hand spreading, as it deposits the sludge in a thin, even layer and is considerably faster.

The remaining sludge from the stock piles is mixed with earth and used for

* Presented at Connecticut Conference of Sewage Works Superintendents; Hartford, Conn.; June 22, 1950.

tree planting and as a sub-base for newly seeded areas. It has been found that the sludge is apparently too strong for grass seedlings; therefore, it is not mixed with top soil for areas to be seeded.

Advantages of Arrangement

The arrangement described has a number of advantages for both departments. The sewer department has an easy and reliable method of getting rid of the sludge and the park department obtains a valuable fertilizer. The park department shop reconditions the sewer department's hand and power mowers in partial repayment for the sludge. In addition, the park department is able to keep its men employed during slack seasons by regrinding, mixing, and spreading the sludge. Also, the park department saves the cost of a corresponding amount of chemical fertilizer. The parks use about 300 tons of sludge, which might have the fertilizing value of 100 tons of fertilizer costing $70 per ton; consequently, the park department saves about $7,000 per year on fertilizer costs.

The park department does not break down its costs so as to show the cost of mixing and spreading the sludge, but the machines now used have cut the labor costs considerably. The latest sludge analysis, made by the Connecticut Agricultural Experiment Station, shows average values of 2.46 per cent total nitrogen and 1.50 per cent phosphoric acid. These figures indicate that by itself the sludge is low-grade fertilizer, but there are a number of benefits that a chemical analysis does not show.

The local park department is glad to take all the sludge that the sewer department produces. It has been found useful in preventing the ground from becoming hard and baked during periods of drought, when park areas remain green while adjacent areas dry out and burn. In addition, the color and texture of the grass has improved and the disease resistance of all plants has been improved. When the sludge has been well digested, no odor complaints have been received from nearby residents. As mentioned before, difficulty has been experienced with newly seeded areas if sludge is mixed with the top soil. However, with the addition of superphosphate, the sludge makes a very good fertilizer and the park department has received many requests for information on fertilizers from property owners who wish to duplicate the park department lawns.

The Greenwich park department maintains four large parks, a number of playgrounds and ball fields, and about 75 small areas and town-owned properties. In all, about 50 acres of grassed areas are cared for.

Those who have seen Greenwich parks will agree that they are well kept and are a credit to the town. The use of sewage sludge has undoubtedly contributed to their fine appearance.

TIPS AND QUIPS

Safety Tips

Small but obvious things often cause accidents. This, coupled with the statement that the accidents found in sewage treatment plants are generally of types found in almost any industry, formed the theme of a paper on "Accident Control in Sewage Treatment," presented at the 1950 Annual Meeting of the Michigan Sewage and Industrial Wastes Association, held May 22-24, at Traverse City. The author, Wendell R. Williams, knows whereof he speaks, as he is supervisor of the Michigan Engineering Department, Employer's Group Insurance Companies.

Some of the points made by Mr. Williams were as follows:

1. Use only equipment that is safe.
2. Never use a ladder on a flat slippery surface without ladder shoes or tying the base of the ladder to prevent slipping.
3. Never paint a wooden ladder, as paint has a tendency to hide small defects. Protection for ladders can be afforded by giving them a coat of linseed oil.
4. Never use "mushroomed" tools.
5. Use hand rails on all stairs.
6. See that all floor openings are properly protected at all times.
7. See that the proper tools are used on each job.
8. Never start a job without giving some thought to the safest way that this particular job can be done.
9. Learn to recognize hazards and proper corrective measures.
10. Always lift with the leg muscles and never with the back muscles.
11. Use safety belts in dangerous atmospheres and provide sufficient aid, outside, to remove workers liable to be overcome.
12. In plants where there is only one operator, have that operator call the police department hourly.

Of all the points made, however, Mr. Williams stressed most heavily the necessity for always being safety conscious.

Panacea for Sewage Problems?

One "miracle" germicide followed another at a recent special meeting of the Passaic Valley (N. J.) Sewerage Commission. As reported in the Newark, N. J., *Evening News* of July 6, the commissioners had already been wrangling among themselves for almost a month on the question of whether to authorize pilot plant tests on a so-called miracle germicide, Perma Cide.

At the special meeting, authorization of the expenditure appeared ready for passage when another miracle chemical made its appearance. Claims for the new entry, called NOR, were that it would not only kill bacteria, but also would eliminate odors and banish mosquitoes and other insects. Furthermore, it is supposed to possess none of the poisonous qualities of its rivals. The developer of this chemical reported that two drops in a cesspool literally chased out the flies and mosquitoes and quickly eliminated the odor.

On the basis of a laboratory test report that showed Perma Cide killed more than 98 per cent of the bacteria in sludge taken from the Commission's system, a 4- to 6-week series of tests was authorized (at $6,000 cost) to determine the action of Perma Cide in one of the system's tanks. Chemical treatment is part of the Commission's quest to meet Interstate Sanitation Commission requirements regarding treatment of sewage more economically than by mechanical treatment.

On the basis of past observations in such matters, we're tempted to editorialize, at least to the extent of a cynical "Oh, yeah?"

Big Business

New York City's sewage works statistics are such as to stagger the imagination. Some indication of the magnitude of the operation involved is contained in the recently published "1949 Annual Report" of the New York City Department of Public Works.

The city's 4,050 miles of sewers handled more than 365,000,000,000 gal. of liquid wastes, of which 164,980,000,000 gal. received treatment in 13 plants handling from 0.7 to 228 m.g.d. An additional 400 m.g.d. will receive treatment in 6 plants now under construction or scheduled for completion by December, 1953, with 571 m.g.d. to receive treatment in 6 more plants scheduled for completion by the end of 1959. Of the sewage receiving treatment in 1949, 118,625,000,000 gal. was handled in activated sludge plants, 20,805,000,000 gal. in chemical precipi-

tation plants, 16,060,000,000 gal. in plain sedimentation plants, and 9,490,000,000 gal. in fine screening plants.

A total of 63,953,475 cu. ft. of solids was captured during the year. Of this quantity, sludge amounted to 63,218,000 cu. ft.; grit, 423,400 cu. ft.; screenings, 287,400 cu. ft.; and scum, 34,675 cu. ft. Dry solids totaled 106,945 tons.

Heat and power requirements used 430,517,500 cu. ft. of sludge gas, with 19,162,500 kw.-hr. of power produced.

During the year, 46,773,000 cu. ft. of sludge (57,784 dry tons) were dumped at sea; 3,325,000 cu. ft. (7,850 dry tons) were dried on sand beds. Scum sold during the year amounted to 1,353,238 wet lb.

The total 1949 operating and maintenance cost of $2,924,546 ($17.71 per m.g.) was divided as follows: salaries and wages $1,530,693; gas and power $610,503; repairs $350,711; chemicals $80,503; and supplies and materials $352,136.

Paying for the Big Business

As with all municipal services, the operation and maintenance of New York City's existing sewerage and sewage treatment facilities, not to mention the $100,000,000 construction and expansion program now underway, requires money—in this case, lots of money. However, the City Council has found what it believes to be a relatively painless method of providing an anticipated revenue of $15,000,000 annually.

To implement the revenue program the City Council recently approved a local law providing for a new sewer rental charge amounting to about one-third of the existing water fee. Income from this source, according to the majority report of the Council's Finance Committee, is to be used "first for the management, maintenance, operation, and repair of the sewer system," with any surplus used for "payment of interest and amortization on present or future intercepting sewers and sewage treatment or disposal works."

Part of the new charges are intended to be levied against "commercial and industrial users of water not now paying real estate taxes, so they would share the cost of sewage disposal of which they now avail themselves."

Another example of applying the principle of "users pay!"

Not Even Safe at Home

Even boilermakers, after a few days at home, have been known to remark that it was good to return to the rest and quiet of the job. A somewhat analogous situation was described in the June, 1950, issue of the *Michigan Sewage Works Bulletin*, as follows:

"George Wyllie, that genial fellow who has been hopping from here to there over, under, and around the debris, litter, and partly completed structures, piping, and equipment at the Lansing, Mich., plant came through without a scratch, but didn't fare so well at his home work. His agility at the plant is somewhat impaired by a leg cast; he fell from a ladder while putting up screens at home."

Did we hear a quiet "We told you so" from the National Safety Council, which has been warning for years that more accidents happen in the home than anywhere else?

Really Fancy Divers

The "No Fancy Diving, Please" item (THIS JOURNAL, Nov., 1949, p. 1090) on the Illinois S.O.W.H.E.S.S. has brought to light an organization of kindred spirits in South Africa. J. A. McLachlan, editor of *Public Health*, the official organ of the South African Branch, Institute of Sewage Purification, apparently has mistaken the welcoming of a new member to the Society of Operators Who Have Experienced Saturation in Sewage as an introduction of a new sewage works

fraternity. Commenting on the previous item, Mr. McLachlan, in the June, 1950, issue of *Public Health*, says:

"We make reference to this movement in America, in order to draw attention to the existence of an exclusive group of sewage workers in Johannesburg, perhaps of even more ancient lineage than that of our American colleagues. The society has up till now been a secret one for reasons already indicated; in fact, so secret that there are many illustrious names on the secret list, who are unaware of their membership.

Perhaps because of the older foundation in time of the local society, degrees as well as the honour of membership are conferred on those complying with the qualifying conditions. Stripped of legal verbiage, these conditions require that candidates shall have suffered total immersion in sewage or a sewage product, and the seniority of the degree (with right to use the initials after one's name as with other reputable degrees) is graduated directly as the degree of submergence but inversely as the distance from the sewage outfall. Thus, total submergence in a well-oxidised sand-filtered effluent and just short of drowning, would only earn a small letter to a minus power, while knee-height submergence in dumped raw sludge might earn a capital letter degree to a positive finite power.

The local honorary secretary would be glad to hear from persons who consider themselves entitled to any degree of membership."

We wonder if scholarships are available for advanced study in the subject!

It's Your Plant

There is a growing tendency on the part of designers of treatment plants to consult with the present or future operators as to details of the plans. This is a good trend. Nevertheless, the operator, in many cases, tries to second-guess the designer on capacities, flow rates, etc., rather than concentrating his attention on details that will make his operation of the new plant or extension easier and more pleasant.

With this in mind, L. R. Jennings, superintendent at Owosso, Mich., has the following advice to offer in the March, 1950, issue of *Michigan Sewage Works Bulletin:*

"The operator should study the plans from the practical operating side. You may have wished that a door or a stairway that has caused miles of extra steps had been in a different place. A stairway might have been built where that iron ladder is. Be sure exits, walks, etc., are in the best locations for ease in getting where you want to go. Such things get mighty important after a hard day of work. I have found that the engineers are more than glad to cooperate, for after all, we are the ones who are going to make these plants work."

Applied Science

Speaking on a recent radio broadcast of the General Electric Science Forum, astronomer Ernest G. Reuning, of the U. S. Naval Observatory, Washington, D. C., gave a fanciful word picture of the things to come with rocket travel beyond the earth's gravitational pull. Among the many effects noticeable in outer space would be the complete absence of weight and direction—with no gravitational pull there can be no "up" or "down." Also, liquids would float in space as spheres, held together only by their surface tensions!

What a possibility this opens for sewage and industrial wastes disposal! No costly sewers or treatment plants would be required, yet stream pollution would become only a historical reference. Each home or factory would need only a stack for launching small rocket-propelled waste containers to a point outside the earth's gravitational field. Once there, the container would be exploded and the wastes would simply float in space, no longer of concern to anyone for untold time to come.

Interplanetary space ships? They would have to be equipped with windshield wipers, of course!

Proceedings of Member Associations

NEW ENGLAND SEWAGE WORKS ASSOCIATION

Spring Meeting

Worcester, Massachusetts, June 1, 1950

The 1950 Spring Meeting of the New England Sewage Works Association, held at the Sheraton Hotel, Worcester, Mass., on June 1, 1950, was attended by 137 members and guests.

The morning session, presided over by President Ralph W. Horne, was devoted to the following technical program:

"Function of Trickling Filters," by Clair N. Sawyer, professor of sanitary chemistry, Massachusetts Institute of Technology.

"Design and Construction of Trickling Filters," by Ariel A. Thomas, assistant engineer, New England Drainage Basin, Public Health Service.

"Acid Iron Wastes," by Worthen H. Taylor, assistant sanitary engineer, Massachusetts Department of Public Health.

A round-table discussion on "Operation of Trickling Filters," led by Stuart E. Coburn, consulting chemist, Metcalf & Eddy, Boston, Mass.

Following luncheon, Thomas C. Sweeney, vice-mayor of Worcester, extended the greetings of the city to the members and guests present.

The afternoon was devoted to consideration of the Worcester sewerage system and disposal works. Paul C. Hedenstad, superintendent of sewers, spoke on "History of Worcester Sewerage System and Treatment Works." Earl R. Perry, superintendent of public works, had as a subject "Protection of New Plant by Rules and Regulations." John Hayden, of Hayden, Harding, and Buchanan, consulting engineers, spoke on "Basic Design Data for New Worcester Treatment Plant"; following his talk he presented an excellent moving picture showing all stages of construction of the new works. The latter part of the afternoon was spent in an inspection of the new trickling filters and secondary tanks. Mr. Hayden presided at the microphone on a sound truck and explained the salient features of the new works. The inspection was curtailed by heavy rainfall, which marred an otherwise interesting and worth-while day.

WALTER E. MERRILL,
Secretary-Treasurer

CENTRAL STATES SEWAGE WORKS ASSOCIATION

23rd Annual Convention

Indianapolis, Indiana, June 9–10, 1950

The 23rd Annual Convention of the Central States Sewage Works Association was held at the Lincoln Hotel, Indianapolis, Ind., June 9–10, 1950. The more than 175 persons who registered for the meeting were welcomed

to the city by James H. Carnine, of the Board of Sanitary Commissioners, Indianapolis.

This was followed by a discussion "Does Your Plant Meet Present Day Design Standards?", led by a panel consisting of G. K. Erganian, Indianapolis, Ind.; A. J. Van Breda, Springfield, Ill.; G. F. Bernauer, Madison, Wis.; and J. A. Drake, Minneapolis, Minn.

The afternoon session on June 9 included the following papers:

"Can a Municipality Dispose of Garbage with Home Grinders?", by L. I. Couch and H. J. Kulin, consulting engineers, Indianapolis.

"Studies of Nitrification in the B.O.D. Test," by A. M. Buswell, chief, Illinois State Water Survey, Urbana, Ill.

"Phosphorus Removal from Sewage Plant Effluents," by W. L. Lea and Gerald A. Rohlich, Madison, Wis.

"Railroad Car Washing Problems," by G. Gutzeit, East Chicago, Ind.

An enjoyable social hour, sponsored by members of the Water and Sewage Works Manufacturers Association, preceded the Annual Banquet. At the banquet an address "What About Socialism?" was given by Marshall D. Abrams, managing director, The Construction League of Indianapolis.

The entire morning session on June 10 was devoted to an "Operators' Breakfast," in which open discussion from the floor was stimulated and guided by a panel consisting of M. L. Robins, Minneapolis, Minn.; W. W. Mathews, Gary, Ind.; Paul L. Brunner, Fort Wayne, Ind.; G. F. Bernauer, Madison, Wis.; James A. Drake, Minneapolis, Minn.; and A. Paul Troemper, Springfield, Ill. The general discussion topic was "Control of Materials Discharged to Sewers," with particular attention being given to water softening sludge, synthetic detergents, grit, and toxic materials.

The afternoon session comprised papers as follows:

"Persistence of Mono-Chlorophenols in Polluted River Water and Sewage Dilutions," by C. C. Ruchhoft and M. B. Ettinger, U.S.P.H.S. Environmental Health Center, Cincinnati, Ohio.

"New Criteria in the Design of High-Rate Trickling Filters," by K. V. Hill, consulting engineer, Chicago, Ill.

"The Wisconsin Stream Pollution Law and How It Will Be Used to Control Industrial Waste Discharges," by T. F. Wisniewski, director, Wisconsin Committee on Water Pollution, Madison, Wis.

Officers elected for 1950–51 were:

President: H. T. Rudgal, Kenosha, Wis.
1st Vice-President: M. L. Robins, St. Paul, Minn.
2nd Vice-President: W. W. Mathews, Gary, Ind.
3rd Vice-President: E. Hurwitz, Chicago, Ill.
Secretary-Treasurer: A. Paul Troemper, Springfield, Ill.

A. Paul Troemper,
Secretary-Treasurer

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

24th Annual Meeting

Cincinnati, Ohio, June 28–30, 1950

With the largest registration to date, numbering 239, the Ohio Sewage and Industrial Wastes Treatment Conference held its 24th Annual Meeting in Cincinnati, Ohio, June 28–30, 1950. The total registration was about evenly divided among those representing municipal sewage treatment, industrial

waste treatment, and manufacturers of treatment equipment. Chairman Robert W. Bowman presided at the conference, assisted by Lloyd C. Huffman at the Operator's Forum and Vice Chairman H. S. Kline and Walter Gerdel at the dual sessions on industrial wastes and sewage treatment.

The morning session on June 28, at a manufacturer's forum stressing instrumentation, heard W. W. Greer of Leeds-Northrup Corporation discuss the application of pH measurement and control to the treatment of industrial wastes, and H. C. Hite, Brown Instrument Division, Minneapolis Honeywell Corporation, discuss flow measurement devices.

The afternoon session opened with an address of welcome by Albert D. Cash, Mayor of Cincinnati. "A More Productive Federation" was then discussed by W. H. Wisely, executive secretary of the Federation of Sewage Works Associations. After a short business session, the rest of the session was devoted to Cincinnati's sewage disposal program. F. C. Tolles presented the Cincinnati program, outlining the details of city sewerage improvements and the new Little Miami plant. A. B. Backherms outlined the program by which these improvements are financed through sewer service charges. H. A. Seaman rounded out the review by presenting the program now in progress in Kentucky.

The Thursday morning session began with an Operator's Forum, presided over by L. C. Huffman, Dayton, Ohio. Subjects brought up for discussion were: clogging of trickling filters media, uses of aluminum base paints at sewage plants, handling of mineral oils and greases at plants, and sewer use ordinances. In regard to the latter, it was agreed that the Federation's Manual No. 3 was a valuable guide.

Following the Operator's Forum, L. A. Danse, industrial representative on the Federal Water Pollution Control Advisory Board, presented a resume of the activities of the Board.

Other papers included the following:

"Water Quality Objectives," by M. LeBosquet, Jr., U.S.P.H.S.

"Water Pollution Mobile Laboratory Operation," by Bruce M. McDill, Division of Sanitary Engineering, State Department of Health, Columbus, Ohio.

In the afternoon session, the approach to industrial wastes problems in Cincinnati was presented. The problem from the city's viewpoint was covered in a paper prepared by the late H. H. Kranz, city engineer. The approaches made by two industries in the area were presented by representatives of Proctor and Gamble and Emery Industries, Inc. For the remainder of the afternoon, two sessions were in progress, devoted to industrial wastes and sewage treatment.

The following papers were presented in the industrial wastes section:

"Treatment of Plating Wastes at Lockland Plant of Electro Auto-Lite Company," by Allen Reed, chemist, Electric Auto-Lite Co., Lockland.

"Experience in General Motors Plants with Chlorination of Cyanide Wastes," by David Milne, E. G. Roy, P. W. Uhl, and C. F. Hauri.

"Application of OCO Water System to Paper Mill White Water Recovery," by G. C. Ehemann, plant engineer, Ohio Boxboard Co., Rittman.

"Evaluation of Waste Disposal Problems of the White Paper Industries," by H. C. Koch, plant chemist, Aetna Division, Howard Paper Mills, Inc., Dayton, Ohio, and R. H. Savage, research director, Mead Corporation, Chillicothe, Ohio.

In the sewage treatment section the following papers were presented:

"Program of Improvement of Sewage Treatment Facilities at State Welfare Institutions," by E. F. Wittmer, sanitary engineer, Ohio Department of Public Welfare, Columbus.

"Air Diffusion with Saran-Wrapped Tubes at the Columbus Plant," by James H. Blodgett, superintendent, sewage treatment plant, Columbus.

"Sludge Digestion Trends," by T. C. Schaezle, senior associate engineer, sewage treatment plant, Akron.

"Report of the Short School for Water and Sewage Treatment Plant Operators," by W. D. Sheets, assistant engineer, Ohio Department of Health.

As usual, one of the highlights of the conference was the Annual Banquet, held Thursday evening. The banquet was preceded by a cocktail hour sponsored by the Water and Sewage Works Manufacturers Association. William A. Heseler, foreign news analyst and newspaper feature writer, spoke on the "cold war" and the Korean situation.

On Friday morning George E. ("Doc") Symons, managing editor, *Water and Sewage Works*, presented a review of "Toxic Wastes in Sewages"; E. J. Cleary, executive secretary and chief engineer, Ohio River Valley Water Sanitation Commission, described the current activities of the Commission toward the elimination of pollution in the Ohio River basin; John S. Delos, chemist, Easterly sewage treatment plant, Cleveland, described the work done in 1949 by the Division of Sewage Treatment on the determination of the effect of pollution on the Cleveland beaches; and John W. Wilson, U. S. Public Health Service, spoke on "The Sanitary Biologist's Contribution to Waste Purification."

The afternoon was left open for field trips. Arrangements had been made to visit the pumping station of the Mill Creek Barrier Dam where, in times of flood in the Ohio River, flood gates are raised and all the water from this tributary area is pumped to the river. Another visit was made to the plating wastes treatment plant at the Electric Auto-Lite Company's Lockland plant.

Officers elected for 1950–51 were:

Chairman: H. S. Kline, Dayton.
1st Vice-Chairman: Walter E. Gerdel, Cleveland.
2nd Vice-Chairman: Donald G. Stevens, Cleveland.
Secretary-Treasurer: John E. Richards, Columbus.

JOHN E. RICHARDS,
Secretary-Treasurer

PENNSYLVANIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

24th Annual Meeting

State College, Pennsylvania, August 23–25, 1950

The 24th Annual Meeting of the Pennsylvania Sewage and Industrial Wastes Conference was held at State College on August 23–25, 1950, in conjunction with the Pennsylvania Water Works Association.

The morning session on August 24 heard a paper on "Pollution Abatement Action in the Ohio River Basin," by Edward J. Cleary, executive director and chief engineer, Ohio River Valley Water Sanitation Commission, Cincinnati, Ohio. Discussions were presented by H. E. Moses, consulting chief engineer, Pennsylvania Department of Health, Harrisburg, and J. F. Laboon, chairman and chief engineer, Allegheny County Sanitary Authority, Pittsburgh.

Concurrent sessions during the afternoon featured an Industrial Wastes Forum and a Sewage Works Forum. The former was devoted to a panel discussion of "Water Pollution Abate-

ment Standards—Their Formulation and Administration," under the leadership of Roy F. Weston, sanitary engineer, Atlantic Refining Co., Philadelphia.

The Sewage Works Forum included the following papers:

"Measuring Sludge Drying Bed Performance," by T. R. Haseltine, partner, The Chester Engineers, Pittsburgh.

"Operation of Radnor-Haverford Sewage Treatment Plant," by Paul Longley, superintendent, Radnor-Haverford sewage treatment plant, Upper Darby.

"Flow Measurements — Metering Methods and Devices," by Robert E. Stiemke, professor of sanitary engineering, Pennsylvania State College.

"The Relation and Interpretation of Laboratory Tests to Sewage Plant Operation," by R. R. Kountz, associate professor of sanitary engineering, Pennsylvania State College.

At the Annual Dinner, FSWA President Arthur H. Niles spoke on "Federation Affairs."

At the morning session on August 25, papers were presented as follows:

"Problems of Organizing and Financing Sewerage Projects," by W. H. Corddry, consulting engineer, Harrisburg.

"Toxic Wastes in Municipal Sewage," by George E. Symons, managing editor, *Water and Sewage Works*, New York City.

"Air Diffusion—A Versatile Tool for Sewage and Industrial Waste Treatment," by Frank C. Roe, Carborundum Co., Perth Amboy, N. J.

Officers elected for 1950–51 were:

President: H. T. Reuning, Ridgway.
1st Vice-President: R. M. Bolenius, Willow Grove.
2nd Vice-President: R. F. Weston, Philadelphia.
Secretary-Treasurer: Bernard S. Bush, Wilkes-Barre.

BERNARD S. BUSH,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Memphis, Tenn.	Oct. 23–25, 1950
North Carolina Sewage Works Association	Washington-Duke Hotel, Durham, N. C.	Nov. 13–15, 1950
Florida Sewage Works Association	Governor's Club Hotel Ft. Lauderdale, Fla.	Nov. 13–15, 1950
Oklahoma Water, Sewage and Industrial Wastes Conference	Oklahoma A. & M. College Stillwater, Okla.	Nov. 27–Dec. 1, 1950
Arizona Sewage and Water Works Associations	Pioneer Hotel Tucson, Ariz.	Nov. 30–Dec. 2, 1950

Reviews and Abstracts*

Microscopic Green Organisms as Agents of Sewage Purification. By A. R. Stone and W. E. Abbott, *Water and San. Eng.*, **1**, 3, 115 (1950).

Sewage placed in shallow troughs (4-in.) outdoors develops a greenish growth, which does not settle, and a brown or greyish sludge, which settles readily. The solids in the dark sludge approximate in dry weight the suspended solids in the settled sewage, but the growth of green organisms replaces the suspended matter in the original liquid. Settled sewage was exposed in primary tanks until it turned green. Part of this green liquid was pumped into primary tank effluent to inoculate the irrigation areas and the residue served as seed for more primary effluent. Fear of excessive development of algae in the irrigation areas and in the river itself were not realized. The growth of the green organisms produces organic matter, which has some power of absorbing dissolved oxygen in the dark, resulting in an increase in B.O.D. Fish culture may be a result of deliberate cultivation of green organisms in sewage. Their cultivation in sewage and discharge into a stream might prove advantageous under critical stream conditions. The assimilation of carbon and nitrogen in the cells of the organisms might prove advantageous for agricultural utilization of sewage constituents if a way could be found to settle and remove these growths.

Methods of sanitary chemical analysis do not distinguish between the putrescible organic matter and newly synthesized organic matter, but in spite of this there is a definite decrease in the B.O.D., due to the growth of green organisms. In a good effluent this growth might lead to an increase in B.O.D. The authors have developed a method of evaluating the photosynthetic factor by determining dissolved oxygen content of samples incubated in the dark and with exposure to light.

H. Heukelekian

The Problem of Safety and Industrial Hygiene in Water and Sewage Works. By Eugeniusz Górecki. *Gaz, Woda i Tech. Sanit.* (Polish), **24**, 103 (Mar., 1950) and **24**, 149 (Apr., 1950).

This is a classification of hazards at water and sewage works according to the scheme in use by the International Labor Bureau, Geneva. A review of existing regulations pertaining to construction practices and crafts as they relate to sewerage and sewage treatment is given; for example, shoring for different excavation depths and soils in sewer excavation to prevent cave-ins, hazards associated with electrical equipment, welding, etc. In sewage works the hazards listed are associated with asphyxiation or explosion in sewers, observation wells, settling, and digestion tanks; electrocution from contact with electrical currents in damp locations; slipping or falling on catwalks, stairs, other slippery surfaces; possibilities of falling or drowning in tanks inadequately lighted or improperly barricaded; drowning in combined or storm sewers, settling, and digestion tanks, etc.; and the possibility of skin diseases from contact with sewage and/or industrial wastes. A listing of 40 regulations pertaining to approved safety and industrial hygiene practices is given. A very extensive discussion is presented of means for identifying and determining amounts of gases in sewers, manholes, etc.

Conrad P. Straub

* Please send to Federation headquarters all perodicals, bulletins, special reports; etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

Sewage Treatment Plant for a Tuberculosis Sanatorium. By Theodat Bilyk. *Gaz, Woda i Tech. Sanit.* (Polish), **24**, 142 (Apr., 1950).

A plant is described which will treat a sewage flow of 42,300 g.p.d. from 600 patients and 400 auxiliary personnel at a tuberculosis sanatorium. The flows contributed by the patients were estimated at 53 g.p.d. and from the other personnel at about 26 g.p.d. An average hourly flow based on 1/16 or the total daily flow and a maximum flow of 1/10 the average flow was assumed. To allow for future expansion, the maximum hourly flow was estimated at 6,350 g.p.h. The plant is enclosed and includes screening, sedimentation and digestion in an Imhoff tank, ventilated high-rate filters, final sedimentation, sand drying of sludge, chlorination, and all necessary appurtenances. The high-rate filters have an area of 356 sq. ft. and are about 13.1 ft. deep. The media consists of three layers, the top and bottom each 1.64 ft. thick with ¾- to 1½-in. stone, and a middle layer 9.8 ft. thick with 1½- to 3-in. The filters will operate at a rate of 21.4 m.g.a.d. at present, or 25.7 m.g.a.d. in the future, with a recirculation ratio of 3.6. The secondary sedimentation tank serves also as an equalizing tank. Chlorine will be added to the effluent at a rate of 2 to 4 p.p.m., or 145 to 290 lb. per day. Sludge will be applied to the sludge drying beds to a depth of about 8 in. and will remain on the beds for 17 days. Outside air used for ventilation will first pass over the sludge drying beds, then through the Imhoff tank room, through the high-rate filter (at a rate of 1 cu. ft. per sq. ft. per min.), and finally through the room housing the secondary filter.

Conrad P. Straub

Treatment of Rice Water. By H. Heukelekian. *Ind. Eng. Chem.*, **42**, 4, 647 (Apr., 1950).

In preparing "Minute Rice," large volumes of wastes are produced from soaking, cooking, and washing processes. A total of about 61,000 gal. of water are used per ton of raw rice processed. The pH of the composite wastes varies from 4.2 to 7.0. The B.O.D. is about 1,000 p.p.m. Starch and sugar account for most of the B.O.D. About 530 lb. of B.O.D. and 730 lb. of solids are produced per ton of raw rice handled. The phosphorous content of the waste is adequate for biological treatment, but the nitrogen content needs supplementation.

Laboratory tests showed that plain sedimentation results in about 30 per cent B.O.D. reduction. Lime treatment of settled liquor gave some additional B.O.D. removal. Anaerobic digestion of the raw wastes gave satisfactory results with B.O.D. loadings of 0.1 lb. per cu. ft. per day and detention times of as low as 1.2 days. Under these conditions, B.O.D. reductions of over 90 percent were obtained. Ammonia was used as a source of nitrogen and as a neutralizing agent. Aeration of the raw waste, with sufficient suitable seed material for 24 hr. and the addition of nitrogen, produced an effluent with 25 to 55 p.p.m. B.O.D.

Paul D. Haney

Wash Water Treatment and Fine Coal Recovery. By E. E. Rickert and W. T. Bishop. *Ind. Eng. Chem.*, **42**, 4, 626 (Apr., 1950).

Run-of-mine coal is prepared for market by separating from the coal the particles having high ash content and by screening the clean coal into various market sizes. The effluent from coal preparation plants contains fine coal and refuse particles suspended in the water used for cleaning and washing. Of the solids contained in the waste water, about 7.4 per cent are retained on a 28-mesh sieve. The refuse content increases as the particle size decreases. The minus 200-mesh particles are highest in ash content, as this material consists largely of colloidal clay. From a stream pollution standpoint, the discharge of these solids is objectionable principally for physical reasons. Silting rates are increased, with consequent damage to recreation and navigation and the creation of flood hazards.

The settling of solids from the water and the disposal of the solids are two steps in the pollution abatement process. Silting basins are frequently used for both settlement and retention of the solids. However, because of large quantities of wash water involved at one coal preparation plant, settling tanks equipped for mechanical sludge removal were installed. The thickened sludge from the settling tanks was then disposed of by various methods,

including processing for coal recovery. Recirculation of wash water after complete clarification is practiced.

Froth flotation is also used to recover fine coal. This is accomplished by rendering the coal particles water repellent by oil treatment, following which a flotation process employing pine oil as a frothing agent is applied.

PAUL D. HANEY

Proceedings of the Fourth Industrial Waste Conference. *Eng. Bull.*, **33**, No. 4 (Extension Series No. 68), Purdue Univ. (July, 1949).

This is a continuation of the contents of this bulletin.

Disposal of Wastes from Small Abattoirs. By ROBERT E. STIEMKE. Pp. 178–202.

The results of treatment at a penitentiary slaughterhouse waste pilot plant are described. Normally, killing occurs twice weekly with 6 to 20 hog units slaughtered each time. All readily separable wastes such as paunch manure, hair, and flesh were excluded, but blood was drained to waste. Flows amounted to 100 gal. per hog and 300 gal. per steer killed. Wastes were settled before secondary treatment, tests showing 1 hr. to be sufficient. B.O.D. concentration of wastes discharged to secondary units ranged from 1,550 to 1,850 p.p.m.

Trickling filter tests were conducted on four 3-ft. units operated at 2 m.g.a.d. and dosed by tipping trays and perforated distributing pans. Results show reductions in B.O.D., including secondary settling, to be approximately 17 per cent without recycling and 33 per cent with recycling.

Sand filters test were made on 3 units, 10-ft. diameter or 10-ft. square, dosed by means of a rotary sprinkler, a motor-driven rotary distributor, and by flooding into a dosing pad. Depth of sand in each was 18 in. Sprinkler results were not considered worth tabulating. Two days' dosing with the rotary distributor showed B.O.D. reductions of 50 and 75 per cent and ponding at the end of the second day. Flooding tests covered two 8-hr. days at rates varying from 50,000 to 200,000 g.p.a.d. Best results were at lower rates, with B.O.D. reductions of 86 per cent obtained for hogs and 84 per cent for cattle.

Most satisfactory results were obtained by chemical treatment in a 400-gal. batch-type plant with a 3-min. rapid mix, a 20-min. slow flocculation, and 2 hr. or less sedimentation. Using either calcium hypochlorite or chlorinated lime and alum at dosages of 0.2 lb. available chlorine per hog unit and 3 to 5 lb. alum per 1,000 gal., reductions of 95 per cent B.O.D. were obtained with little technical control. The effluent had no taste or odor and a turbidity less than 5 p.p.m. Cost of chemicals ranged from 7.5¢ to 12.5¢ per hog unit.

Food-Processing Waste Treatment in Wisconsin. By T. E. WISNIEWSKI. Pp. 203–207.

This is a resume of the organization and work of the committee on water pollution, particularly in regard to chemical precipitation of cannery wastes, reported in a booklet in 1939, and lagooning of wastes, reported in a booklet in 1945. Since 1938 only one chemical precipitation plant has been constructed, canners preferring treatment in lagoons or municipal plants. Only in cases of poor maintenance has lagooning been unsuccessful.

Nitrate Treatment of Lagoons. By H. H. YOUNG, Pp. 208–210.

The important points in construction and operation of cannery waste lagoons, such as area, proximity to plant, capacity, freeboard, and seeding, are discussed. Stokely Foods' experience has shown the following sodium nitrate dosage needed in the waste, per 1,000 cases No. 2 cans packed, to eliminate objectionable odors: lima beans, 60 lb.; pumpkin 150 to 200 lb.; peas, 200 lb.; tomato or corn, 200 to 250 lb.; and most others, 150 lb. Larvicidal spraying is needed to keep down fly and mosquito breeding.

Analytical Determination of Metals Affecting Sewage Treatment. By M. L. RIEHL AND E. G. WILL. Pp. 211–222.

In order to study metallic wastes in sewages, the Ohio Department of Health engineering laboratory made an extensive study of existing analyses for various metals and therefrom selected and developed analyses which they now use. Most analyses are made on acid solutions of ashed samples. The methods for ashing both sewage and sludge samples are described.

In most cases, separate tests are outlined for samples of low and high concentrations, although in the case of the non-metallic cyanide four tests are mentioned, one being given in detail. Metals covered are iron, copper, nickel, chromium, zinc, and cadmium. References are made to all texts from which analyses were derived.

Special Tests for Industrial Wastes. By W. D. Hatfield. Pp. 223–225.

This principally describes methods used to determine excessive waste discharge from corn milling plants. Two equal samples are collected hourly, one being composited and the other stored as collected. At the end of the day, if an oxygen-consumed test on the composite shows excessive wastes were discharged, the type, concentration, and time are determined by special tests on the 24 separate samples. Tests are outlined for rapidly determining types of waste and chlorine demand. Reports to the industry enable it to check on plant operation and bring about cooperation that keeps the Decatur, Ill., plant operating efficiently.

Accidents with Cyanide Plating Solutions. By Perry E. Miller. Pp. 226–228.

Fourteen cases are described where cyanide plating solutions discharged to streams killed fish or animals. The reasons for excessive discharge were failures to provide adequate supervision, maintenance, safeguards, instructions to employees handling materials, and storage or disposal facilities.

The Toxicity of Hexavalent Chromium to Sunfish and Bluegills. By C. W. Klassen, W. A. Hasfurther, and M. K. Young. Pp. 229–237.

The Illinois Sanitary Water Board and Electric Auto-Lite Company ran a series of toxicity studies covering nearly two years, to determine the tolerance of small fish to plating wastes containing hexavalent chromium. Fish were carefully acclimatized, and most variables were eliminated so that death could be attributed to the chromium alone. Tests were conducted in hard-water solutions.

Results of twelve successful tests using four to twelve fish in each showed, in general, that over 50 per cent of the fish survived 30 days in concentrations of chromium as high as 49 p.p.m. Internal examinations at this limit showed no unusual characteristics, but at higher concentrations the fish that died showed signs of deterioration, orange-yellow fluid in the body cavity, discolored liver, and ruptured spleen. Details of test preparation and summaries of each test are given.

Methods of Disposing of Cyanide Wastes. By R. L. Kessler and R. W. Oyler. Pp. 244–249.

Plant reconversion resulting in rapid expansion of cyanide plating and heat treating necessitated an emergency program to keep cyanide content of the process water under 2 p.p.m. The procedures inaugurated and described were: (1) Reclaim tanks were added; (2) a collection system was devised for waste paint, grease, oil, solvents, etc.; (3) the use of cyanide cleaners and dips was discontinued; (4) alkaline and acid wastes were disposed of together; and (5) destruction of cyanide wastes in other than rinse waters was begun.

In studying use of reclaim tanks it was found necessary to reduce drag-in to the plating tank by tumbling or air-blowing parts before plating. Concentrated wastes are collected in special containers and the batch treatment with chloride of lime is described. An interesting procedure is given for the removal of cyanide from solid wastes. Proposals are also given for improving drag-out control, detection of leaks in heat exchangers, and chlorination of rinse waters.

Wm. A. Hasfurther

Organization and Financing of Maryland Sanitary Districts—A Panel Discussion. *Jour. Amer. Water Wks. Assn.*, **42**, 118 (Feb., 1950).

Organization Procedure. By I. Alvin Pasarew.

At present there are three main sanitary districts operating in the state of Maryland, but existing legislation provides for five other districts. A list of these districts is given, with the enabling act for each.

The importance of public health education as a means of promoting a sanitary district is stressed. Once the desire is present contact should be made with the

county commissioners, the county engineer, and the county health officer in order to secure action. It is then necessary to determine the engineering feasibility of the project and the ability to finance it. Passage of the enabling act by the legislature will depend on proper ligislation for the new sanitary commission and the backing of local and state governmental units.

Emphasis is placed on the unsolved problem of providing adequate sanitary facilities for scattered rural communities, as the economic aspects are more difficult. Joint action of local areas with the state is a suggested method of possible solution.

Methods of Financing. By N. L. Smith and A. B. Kaltenbach.

The state enabling act creating sanitary districts in Maryland provides the power to finance the projects through levies on the persons or properties within the boundaries of the district. General obligation bonds, revenue bonds, and special assessments may be used separately or in any combination desirable. Special mention is made of the Baltimore County Metropolitan District, which uses a combination of all three methods. Detailed data on the property classifications and extension agreements of this District are presented and should be of interest to those persons connected with financing problems of sanitary districts.

Robert P. Lowe

Public Authorities of Pennsylvania. By J. Raymund Hoffert. *Jour. Amer. Water Wks. Assn.*, **42**, p. 127 (Feb., 1950).

This paper gives an able presentation on the enabling legislation, organization, and problems of authorities in Pennsylvania. Present legislation is derived from the "Municipalities Act of 1945", and a 1947 amendment that still further increased the scope of authorities. The authorities are granted and may exercise all powers necessary or convenient for carrying out their purposes. However, their existence is limited to 50 years, and the maturity of their bonds to 40 years, with no refunding bonds to have a maturity date beyond the life of the authority. It is also stated that the scope of activities shall be in the nature of noncompetitive facilities needed by a municipality.

The two most important requirements for an authority are that it shall not pledge the credit of the government creating it and that it shall provide a self-liquidating service, the charges for which shall amortize the original cost and meet all operating expenses, repairs, and depreciation, as well as furnishing, usually, some reserve against emergencies.

At present Pennsylvania has 96 authorities created solely or in part to construct, acquire, or improve water works, and at least 32 have been created in whole or in part to provide sewerage. The present stream pollution abatement program of the Sanitary Water Board of Pennsylvania is expected to require the formation of many more authorities for sewage treatment.

It is pointed out that administration equivalent to a private business is necessary for the proper functioning of an authority. This includes finance, labor relations, public relations, etc. An unsound project under an authority cannot be financed, because bond buyers cannot be found except at a prohibitive cost and upon a speculative basis. One controlling factor pointed out is that investment firms are unwilling to underwrite bonds for sewerage projects when the annual rental would exceed $35 per house connection.

Many legal problems have arisen from the operation of authorities, but the courts have given favorable interpretation for them and clarified their limitations. Authorities have certain legal and financial problems not common to private enterprise, in compensation for certain powers which they possess beyond those of private enterprise. It is also evident that authorities cannot provide services beyond the ability of the taxpayers to meet the cost.

Robert P. Lowe

Research on the Disposal of Radioactive Wastes. By O. R. Placak and R. J. Morton. *Jour. Amer. Water Wks. Assn.*, **42**, p. 135 (Feb., 1950).

This paper is an attempt to give some idea of the problems involved in waste disposal that result from the production and use of radioisotopes. It also covers the program of investigations on such wastes at Oak Ridge and those being conducted elsewhere.

Control of wastes is based on prevention of additional artificial exposure to radiation that is beyond the level of that produced by naturally occurring radioisotopes. The exposure to radiation is not new; it has always been a part of life. The difference is one of degree. Radioactivity in the Clinch River below Oak Ridge is limited to 10^{-7} microcurie per milliliter. Due to the lack of knowledge about some aspects of the subject this value includes a safety factor of the order of 100.

The variety and magnitude of the materials dealt with adds to the problem of their control. The "indestructibility" of radioactive material needs to be considered. It will not grow or propagate itself like coliform organisms, but neither can it be destroyed as they can, by chlorination. As neither destruction nor neutralization can be used for control, there are only two alternatives for its disposal—concentration and storage, or dilution and dispersal. Natural decay (from a few days to thousands of years) can then reduce the radioactivity. In the event of dispersion of radioactive material, consideration must be given to the possibility of subsequent reconcentration in muds, algae, vegetation, and animal life. Fortunately, a large portion of the radioisotopes dealt with do not fall into the classifications that have an extremely long half-life.

Research on the waste disposal problem is highly emphasized and may generally be divided into fundamental research, to obtain detailed knowledge of the behavior of radioactive materials in air, water, soil, plants, animals, and man, and development of methods of preventing radioactive materials from producing damage to man, animals, or plants.

All of the Atomic Energy Commission installations are engaged in pertinent research, either on waste disposal or on environmental effects, or both. For example, at Los Alamos, N. Mex., in cooperation with the U. S. Public Health Service, the removal of plutonium by activated sludge systems has been studied and other means of removal, using essentially a sanitary engineering approach, are being investigated.

The AEC subsidizes a number of other research projects, which should furnish valuable information to those connected with water and sewage facilities. New York University is studying waste disposal in sewers; Johns Hopkins is investigating the adsorption and assimilation of radioactive materials by bacterial slimes; and Massachusetts Institute of Technology is doing research on radioactive waste removal by water treatment processes.

The Health Physics Division program of research on waste disposal at the Oak Ridge National Laboratory is a cooperative project with the U. S. Public Health Service, the Tennessee Valley Authority, and the Oak Ridge office of the AEC.

ROBERT P. LOWE

Pennsylvania's Clean-Streams Program. BY HOWARD E. MOSES. *Jour. Amer. Water Wks. Assn.*, **42**, p. 146 (Feb., 1950).

The superior use of streams for public water supplies is considered in this paper. However, animal and aquatic life, industrial water supply, and recreation are also important justifications of the clean-streams program in Pennsylvania. The importance of water supply is evident when it is realized that the majority of the large public water supplies in this state are secured from surface streams.

The two main types of pollution are sewage and industrial wastes. Any measures taken to decrease the sewage pollution load will also reduce the hazards existing wherever water is taken from a sewage-contaminated stream. In a highly industrialized state such as Pennsylvania, the industrial waste problem is large both in volume and variety, and the importance of these wastes and the difficulty of solving some of their treatment problems has been comparatively recently realized.

The Pennsylvania program has been based on a careful appraisal of the streams in the state. The policy for stream pollution control requires all sewage to be treated "at least to a primary degree," with such additional treatment as might be required in individual localities; an equivalent degree of treatment is required of industrial wastes. Subsequently, the Sanitary Water Board began the issuance of notices to municipalities and the polluting industries, requiring the preparation and submission of plans for treatment works. To aid this feature of the program, the Health Department was empowered

by law to make grants-in-aid to municipalities, not to exceed 50 per cent of the cost of plan preparation. Up to the present, $750,712.41 has been distributed, and recently actual construction of treatment works has been ordered in the Delaware River basin.

To date great progress has been made in certain areas. All of the collieries at the headwaters of the Schuylkill River have installed plants for silt removal. Philadelphia has a $60,000,000 program for the collection and treatment of its sewage well under way. Standards of waste quality have been adopted through the cooperation of some types of industry and others are in the progress of doing so. Research programs are under way at the Mellon Institute and Pennsylvania State College. Special studies have already been made on two streams. In summarizing, it is felt that the public has become more stream pollution conscious and that accomplishments thus far obtained give a favorable outlook for the ultimate success of this endeavor.

ROBERT P. LOWE

The Optimum Incubation Temperature for the Primary Isolation of Coliform Organisms. BY JOANNA R. BONIECE AND W. L. MALLMANN. *Jour. Amer. Water Wks. Assn.*, **42**, p. 155 (Feb., 1950).

This interesting paper describes investigations to determine whether the optimum temperature for the growth of coliform organisms in their normal habitat (37°C.) is also the optimum growth and fermentation temperature after these organisms have existed in water for some time at temperatures normally much lower than 37°C. Intestinal organisms that exist for extended periods in water at temperatures usually much lower than 37°C. conceivably might become so adapted to those lower temperatures that a relatively sudden return to the temperature of their normal environment could seriously impair their ability to survive and multiply.

The investigation was undertaken to determine the optimum temperature for the primary isolation of coliform organisms from water. The first phase of the study involved growth curve determinations at 32°, 35°, 37°, and 39°C. for representatives of the coliform group. The organisms used were *Escherichia coli*, *Aerobacter aerogenes* and *Intermediate* I. The second phase of the study pertained to the actual isolation of coliform organisms from samples of various types of contaminated water for the above temperatures and for each of the above organisms alone or in various combinations.

This work resolved itself into the following conclusions:

1. The normal optimum growth temperature for *E. coli* and *Aer. aerogenes* is in the 37° to 39°C. range.
2. The normal optimum growth temperature for *Intermediate* I is approximately 35°C.
3. The most favorable incubation temperature for the primary isolation of coliforms from water is 35°C.
4. Incubation at 32°C. for primary isolation is also superior to 37°C., although a longer incubation period is necessary at 32°C. than at 35°C.

ROBERT P. LOWE

Experimental Heated Sludge Digestion. BY JOHN FINCH. *Water and San. Eng.*, 1, 2, 54 (June, 1950).

The experiments were designed to explore the possibilities of digesting sludges in heated closed tanks because of the difficulties encountered in the existing but inadequate facilities at the Rotherham, England, plant. The sewage contains considerable amounts of trade wastes.

The 1,000-gal. experimental digester was heated with an internal hot-water coil. The tank contents were kept between 80° and 85° F. and circulated by a pump every hour for 5 min. Sludge was fed in a ratio of 3 parts of excess activated sludge to 1 part of primary sludge. Digestion was started by adding lime. Experiments showed that the tank could be loaded at the rate of 1.8 cu. ft. digester capacity per capita and produce a digested sludge of 2.8 per cent solids, of which 63 per cent were volatile. The gas yield was 8.8 cu. ft. per lb. of organic solids, with 73 per cent methane and a B.t.u. value of 650. Loadings higher than this slowed up the digestion with a drop in gas yield. It was concluded that the detention period should be 26 days for heated one-stage digestion.

H. HEUKELEKIAN

Separation of Oil Refinery Waste Waters. By Roy F. Weston. *Ind. Eng. Chem.*, 42, 4, 607 (Apr., 1950).

This paper discusses the problems of oil removal from oil refinery waste waters. The problems are those of separation, collection, and reconditioning of oil for recharging to refinery processes, and treatment of waste water for satisfactory disposal.

The efficiency of the gravity differential separator must be based on the relative amounts of that portion of the oil amenable to this type of separation, as oil may be nonseparable because emulsified, etc. An analytical procedure to determine susceptibility to separation has been devised. The "susceptibility-to-separation" (S.T.S.) number is equal to the oil concentration, expressed in p.p.m., present in the central layer of a settled sample. Typical "susceptibility-to-separation" data for various separators are presented.

Study of a large number of well-designed separators might indicate an average effective diameter of oil droplet that would provide a practical basis for design. A droplet diameter of 0.02 cm. is the present size suggested by the American Petroleum Institute for use in separator design.

Separated oil will contain suspended solids and water, which may interfere with its efficient processing, and it is necessary to treat such oil prior to recycling in the refinery process. Typical data on oil treatment are given.

Typical data are presented on an automatic backwash filter for polishing the effluent from a separator. Return of backwash water to the separator influent has only a minor influence on the effluent quality.

Probably the most satisfactory process for removing constituents causing B.O.D., taste, and toxicity is biological treatment. Typical data are presented from the operation of duplicate single-stage 6-in. diameter, 6-ft. deep trickling filters operating at a 15-m.g.a.d. rate and followed by 2-hr. sedimentation. No nutrient materials are added and the efficiencies are comparable to those obtained from sewage treatment filters (of the order of 80 to 85 per cent under normal conditions). B.O.D. loading is in the neighborhood of 2,500 lb. per acre-ft. Oil removal efficiencies approximated those for B.O.D. Indications to date are that oil concentrations as high as 100 p.p.m. have no retarding effects on B.O.D. removal. A significant portion of the oil feed to the filter is not oxidized and is recovered in the final tank sludge.

Oil removal is becoming more difficult as new processes conducive to emulsion and nonseparable suspension formation are installed at refineries. Refinery waste disposal operating and cost data are presented.

Paul D. Haney

Treatment of Compressed Yeast Wastes. By Willem Rudolfs and Eugene H. Trubnick. *Ind. and Eng. Chem.*, 42, 4, 612 (Apr., 1950).

Wastes from compressed yeast manufacturing contain dissolved organic substances. At one plant spent nutrient constitutes 15 per cent of the total volume of waste. This waste has a B.O.D. of 2,000 to 15,000 p.p.m. and accounts for 70 per cent of the pollution load from the plant. Combined wastes from the plant have been treated for more than 5 yr. by a combination of anaerobic digestion and trickling filters. The plant consists of equalization tanks, digesters, trickling filters, and appropriate settling tanks. B.O.D. reductions of as high as 95 per cent and 75 per cent were obtained with the digesters and trickling filters, respectively.

The ripe sludge used as seed for the digesters has remained alive during the 5 yr. of plant operation. The most significant factor influencing digester performance is the load applied daily to the digesters, the B.O.D. removal being a function of the number of pounds applied. Peak digester efficiency occurs at a B.O.D. loading of 0.1 lb. per cu. ft.

The B.O.D. removal by the trickling filters is also a function of the applied B.O.D. load. Recirculation at a 1:1 ratio does not appear to improve plant performance. Loadings in excess of 8 lb. of B.O.D. per cubic yard per day were applied before any great decrease in filter efficiency was noted. Over the loading range of 0.2 to 8.0 lb. B.O.D. per cu. yd. per day the filter efficiency varied from 58 to 40 per cent. B.O.D. reductions of 75 per cent were obtained at 0.1-lb. loadings. Dilution of the filter influent with constant B.O.D. loading improves filter performance. Dilution was accomplished with

cooling water. Optimum B.O.D. removal occurs when the filter influent pH is about 7.0.

PAUL D. HANEY

Chemical Treatment of White Water. BY E. G. KOMINEK. *Ind. and Eng. Chem.*, **42**, 4, 616 (Apr., 1950).

Pulp and paper mills discharge wastes containing fibers and fillers which are called "white water." Clarification of white water by chemical treatment and sedimentation can be accomplished if effective mixing and recirculation are used. Removal of more than 95 per cent of suspended solids is obtained by treatment with alum and activated silica. An alum dosage of 2.0 lb. per 1,000 gal. is effective for fiber removal. Sedimentation may be adversely affected by entrained air, but this can be overcome by the installation of an air separation unit. Slurry recirculation eliminates thermal upsets. The value of the recovered fibers helps defray operating expenses.

PAUL D. HANEY

Treatment of Cotton Finishing Waste Liquors. BY GEORGE G. BOGREN. *Ind. and Eng. Chem.*, **42**, 4, 619 (Apr., 1950).

This paper describes pilot-plant experiments on wastes from caustic and peroxide kiers, bleaching, dyeing, mercerizing, etc. Wash waters and domestic sewage were also involved. The average composition of the wastes during pilot-plant operation was: B.O.D., 280 p.p.m.; pH, 10.5; settleable solids, 0.5 per cent; turbidity, 200 p.p.m.; oxygen consumed, 340 p.p.m.

The pilot plant consisted of a rectangular trickling filter, to which was applied effluent from an existing settling basin. The trickling filter was followed by a secondary settling basin. The pilot-plant filter carried daily B.O.D. loads as high as 30 lb. per cu. ft. and operated at a rate of nearly 10 m.g.a.d. Filter B.O.D. removal efficiency reached a maximum of about 60 per cent. All caustic alkalinity was converted to carbonate or bicarbonate during passage of the waste through the filter.

PAUL D. HANEY

Treatment of Cotton Printing and Finishing Wastes. BY STUART E. COBURN. *Ind. and Eng. Chem.*, **42**, 4, 621 (Apr., 1950).

This paper describes pilot-plant studies on wastes from a textile mill engaged in the printing and finishing of cotton and rayon textiles. These studies included chemical precipitation and high-rate trickling filtration. On an annual basis, trickling filtration was found to be the cheapest method.

Wastes on which the tests were run were warm, highly colored, turbid, and had a pH of over 11. Organic matter, as measured by the oxygen consumed test, averaged about 125 p.p.m. The 5-day B.O.D. averaged about 100 p.p.m.

Chemical precipitation tests using alum and clay and alum were run. Chemical precipitation improved the quality of the wastes. B.O.D. reduction was about 45 per cent.

Trickling filter tests indicated that over 60 per cent of the B.O.D. could be removed from sulfuric acid-conditioned wastes by treatment on high-rate trickling filters. Wastes and recirculated effluent were applied at the rate of about 70 m.g.a.d. (recirculation 4:1). The suspended matter in the filter effluent did not settle readily.

PAUL D. HANEY

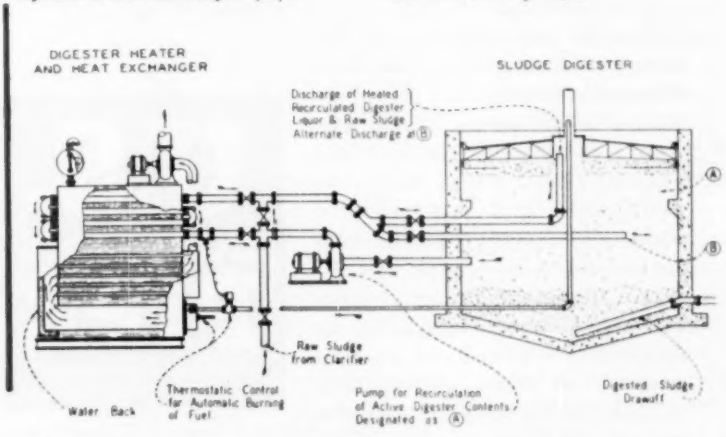
THIS METHOD OF ACCELERATING DIGESTION MAKES SENSE !

Four No. 500 P.F.T. Digester Heaters and Heat Exchangers serve 4 85' and 6 50' P.F.T. Floating Cover Digesters at Dayton, Ohio. L. C. Hoffman, Engineer.

It has been found that action of the methane producing bacteria is less deterred by temperatures above or below the optimum than by fluctuations in temperature. P.F.T. Digester Heater and Heat Exchanger units provide a safe, practical and economical means of maintaining sewage sludge undergoing digestion at an optimum temperature.

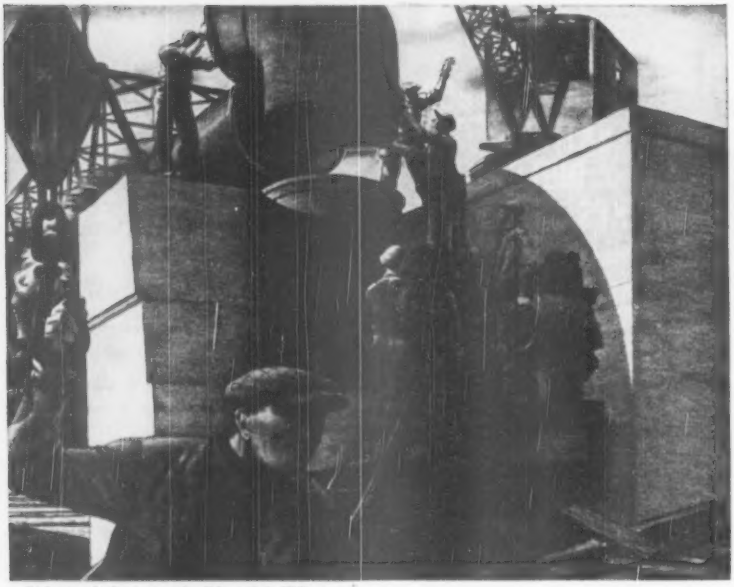
Furthermore, there are no coils of piping in the digestion tank to become caked with sludge and therefore insulated against proper heat transfer. Circulation is such that a more uniform temperature is maintained throughout the sludge mass.

P.F.T. Digester Heaters employ methane gas from the digestion tank for fuel. P.F.T. Gas Engine Heat Exchangers employ heat from sludge gas engine jacket cooling water to keep the sludge at optimum temperature. A list of installations to date is available on request to Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago 13, Ill.


DIGESTER HEATER AND HEAT EXCHANGER
SLUDGE DIGESTER
Discharge of Heated Recirculated Digester Liquor & Raw Sludge Alternate Discharge at (B)
(A)
(B)
Raw Sludge from Clarifier
Water Back
Thermostatic Control for Automatic Burning of Fuel
Pump for Recirculation of Active Digester Contents Designated as (B)
Digested Sludge Drawoff

OTHER P.F.T. EQUIPMENT INCLUDES:
Floating Covers, Gas Safety Equipment, Rotary Distributors, Sprinkling Filter Nozzles, Siphons, Pre-Aerators and Gages.

P.F.T. PACIFIC FLUSH TANK CO.
SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1911
4241 RAVENSWOOD AVENUE CHICAGO 13, ILLINOIS
NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • DENVER • TORONTO



Lithographed on stone by Edward A. Wilson

"Meet the customers' needs" has been our watchword for more than fifty years. Whether it's pipe seven feet, or a few inches, in diameter —or a complicated fitting—or a special casting—we have the equipment and the technical skills to meet almost any need for cast iron pressure pipe and fittings. Taking advantage of process developments and utilizing scientific methods to control quality, our plants are regularly manufacturing products that adequately meet our customers' exacting requirements. United States Pipe and Foundry Company, General Offices: Burlington, New Jersey. Plants and Sales Offices Throughout U.S.A.

U.S.
cast iron
PIPE
FOR WATER, GAS, SEWERAGE AND INDUSTRIAL SERVICE

Low Cost Sludge Incineration

Low cost operation of Nichols Multiple Hearth Incineration at Minneapolis-St. Paul Sanitary District proved over a ten-year period.

Year	Tons Incinerated		Total Cost Operation & Maintenance	
	Dry Solids	Wet Cake	Per Ton Dry Solids	Per Ton Wet Cake*
1940	37,091	116,000	$1.36	$.436
1941	35,993	112,000	1.23	.394
1942	33,838	106,000	1.17	.375
1943	32,955	103,000	1.39	.445
1944	33,758	105,500	1.27	.407
1945	32,428	101,000	1.38	.442
1946	33,581	105,000	1.54	.493
1947	36,633	114,000	1.42	.455
1948	34,549	108,000	1.79	.573
1949	34,787	108,500	1.73	.554
Average	34,563	107,900	$1.43	$.457

*Based on average of 68% moisture in filter cake

When increasing population requirements necessitated additional incinerator capacity, the Nichols Multiple Hearth Furnace was again selected. This fourth unit will be in operation shortly.

The operation costs shown in the table* include all salaries, wages, materials, supplies, power, light, water and miscellaneous charges. Also accounted for are all labor costs and materials required for maintenance of the sludge incinerator equipment.

Despite steadily increasing hourly rates for labor and increasing prices of materials and supplies, the attention to operation and maintenance given by the staff has kept operating costs per ton at a low level.

**Figures taken from Annual Reports of Minneapolis-St. Paul Sanitary District 1940-1949.*

NICHOLS ENGINEERING & RESEARCH CORPORATION
70 PINE ST., NEW YORK 5, N. Y.
40 S. Los Robles Ave. Pasadena, Calif. • 1477 Sherbrooke St. West, Montreal 25, Canada

Now available . . .

TWENTY-YEAR INDEX

SEWAGE WORKS JOURNAL

1928—1948

AUTHORS • SUBJECTS • GEOGRAPHICAL

Here is the key to the great reservoir of fundamental knowledge that is stored in the 115 numbers of the JOURNAL that record the era of greatest progress in water pollution control. Almost 9000 entries are compiled and arranged for finger-tip location with maximum convenience and economy of time. Covers completely the entire content of the first twenty volumes of the JOURNAL. Bound in buckram, 144 pages.

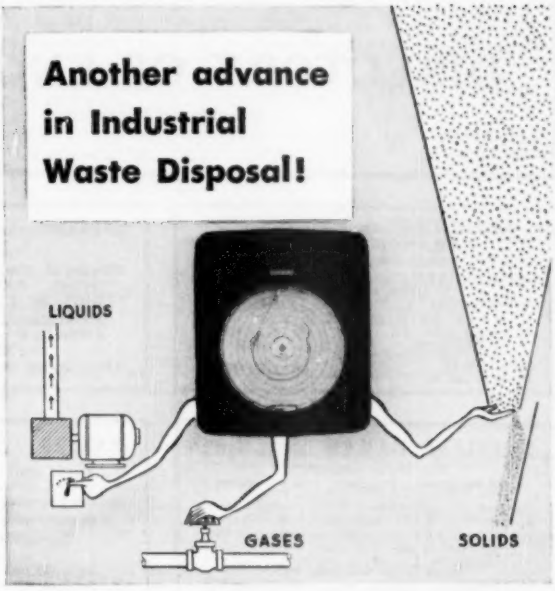
Price — $4.50

Order your copy now from

THE GARRARD PRESS

119 W. PARK AVE.

CHAMPAIGN, ILLINOIS



AUTOMATIC CONTROL for Proportioning of Treating Chemicals

Feeding of treating chemicals at rates proportionate to flow can *now be done automatically* — with total elimination of time-consuming, periodic adjustment of feeders and pumps. In addition, the proportioning of chemicals is far more accurate, which means a more uniform, satisfactory effluent and a definite saving in cost of chemicals.

The instrument control system is properly engineered for individual plant conditions. Its design depends upon the quantity, corrosive quality, and viscosity of the activated silica, carbon dioxide, soda ash, lime, or other chemicals employed . . . also upon the amount of chemicals to be stored and the type of plant operation.

Virtually *any* set of conditions can be met with one or another of the following instrument control methods offered by Foxboro:

1. *ratio flow control with pneumatic control valves for liquid chemicals or gases.*

2. *control of motor operation on dry feeders or on proportioning pumps by "pulse-time" control.*

3. *motor speed control on dry feeders or proportioning pumps through electronic control of power input.*

One of these methods may bring substantial new economies to the operation of your waste disposal system. For engineering briefs on industrial waste surveys, chemical control systems, and disposal methods, write **The Foxboro Company, 162 Neponset Ave., Foxboro, Mass., U.S.A.**

FOXBORO Instrumentation
REG. U. S. PAT. OFF.
INDICATING • RECORDING • CONTROLLING

DIRECTORY OF ENGINEERS

(Continued to page 30)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING VALUATIONS
REPORTS LABORATORY
Suite 1509-18, 121 S. Broad St. PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building Chicago

MICHAEL BAKER, JR., Inc.
The Baker Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER, NELSON & WOODMAN
Civil and Sanitary Engineers
Water Supplies Water Treatment
Sewer Systems Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 Crystal Lake, Illinois

W. H. & L. D. BETZ
Consulting Engineers
Industrial Waste
Industrial Water
Analysis Design
Investigations Operation
Gillingham & Worth Sts. Philadelphia 24, Pa.

CLINTON L. BOGERT ASSOCIATES
Consulting Engineers
CLINTON L. BOGERT IVAN L. BOGERT
J. M. M. GREIG ROBERT A. LINCOLN
DONALD M. DITMARS ARTHUR P. ACKERMAN
Water and Sewage Works
Refuse Disposal Industrial Wastes
Drainage Flood Control
624 Madison Ave, New York 22, N. Y.

BLACK & VEATCH
Consulting Engineers
SEWAGE - WATER - ELECTRICITY - INDUSTRY
Reports, Design, Supervision of Construction
Investigations, Valuation and Rates
4706 Broadway Kansas City 2, Missouri

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal —Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street New York 3, N. Y.

Take advantage of the services of these outstanding consultants!

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Water supply, treatment and distribution
Sewage and industrial wastes disposal
Investigations, reports, appraisals, rates
Airports Municipal Engineering Supervision
584 E. Broad Street — Columbus 15, Ohio

BURNS & McDONNELL
Consulting and Designing Engineers
Kansas City 2, Mo. P.O. Box 7088
Cleveland 14, Ohio 1404 E. 9th St.

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. — Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — Designs and Surveys, Planning, Bridges
WATER WORKS — Roads and Streets, Airports, Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification, Sewerage Systems, Sewage and Industrial Waste Treatment, Power Development and Applications, Investigations and Reports, Valuations and Rates.
210 E. Park Way at Sandusky, Pittsburgh 12, Pa.

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. — Chicago 11, Ill.

OSCAR CORSON
Consulting Engineer
Sewage and Industrial Waste Problems
Drainage—Water Supply—Airfields
Plans—Supervision—Surveys
902 Highland Avenue — Ambler, Pa.

Damon & Foster
Consulting Civil Engineers and Surveyors
Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision
Sharon Hill, Pennsylvania

FREDERICK H. DECHANT
ENGINEER
Chairman of the Board, Frederic R. Harris Inc.
Water Works, Industrial Wastes, Sewerage, Recovery Processes, Hydraulic Works, Gas Plants
Philadelphia: Fidelity Phila. Trust Bldg.
New York: 27 William St.

DE LEUW, CATHER & COMPANY
Water Supply — Sewerage
Railroads — Highways
Grade Separations—Bridges—Subways
Local Transportation
Investigations — Reports — Appraisals
Plans and Supervision of Construction
150 North Wacker Drive — Chicago 6
605 Colorado Bldg. — Washington 5

ECKENFELDER ASSOCIATES, INC.
Sanitary Chemists
Sewage and Industrial Waste Surveys, Process Research and Development, Water Analysis, Stream Pollution Investigations, Laboratory Analyses and Reports
45 N. Broad Street — Ridgewood, N. J.

FAY, SPOFFORD & THORNDIKE
ENGINEERS
CHARLES M. SPOFFORD — RALPH W. HORNE
JOHN AYER — WILLIAM L. HYLAND
HION A. BOWMAN — FRANK L. LINCOLN
CARROLL A. FARWELL — HOWARD J. WILLIAMS
Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment—Airports
Investigations and Reports — Designs
Supervision of Construction — Valuations
Boston — New York

It pays to secure competent and experienced engineering advice!

EDWARD A. FULTON
Consulting Engineers
Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control
3299 Brown Road — Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS
Water Works—Sewage
Industrial Waste & Garbage Disposal
Roads—Airports—Bridges &
Flood Control
Town Planning Appraisals
Investigations & Reports
Harrisburg, Pa. — New York, N. Y.
Scranton, Pa. — Pittsburgh, Pa.

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports
New York — READING, PA. — Washington
Houston — Philadelphia

IVAN M. GLACE
Consulting Sanitary Engineer
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction, and Supervision of Operation
N. Front & Boas Sts. — Harrisburg, Penna.

WILLIAM A. GOFF, INC.
General Engineering and Consulting Services
Water, Sewerage, Refuse Incineration
Industrial Buildings, Power Plants
Airports, Town Planning
Plans, Supervision, Valuations, Reports
Broad St. Station Bldg., Philadelphia 3, Pa.

ONLY $60 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage works field and will afford maximum prestige!

GREELEY & HANSEN
Engineers
Samuel A. Greeley — Paul Hansen (1920–1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke
Water Supply, Water Purification
Sewerage, Sewage Treatment
Flood Control, Drainage, Refuse Disposal
220 S. State Street, Chicago 4

HAVENS AND EMERSON
Consulting Engineers
W. L. Havens — C. A. Emerson
A. A. Burger — F. C. Tolles — F. W. Jones
Water, Sewage, Garbage, Industrial Wastes, Valuations.—Laboratories
Leader Bldg. — Woolworth Bldg.
Cleveland 14 — New York 7

HAYDEN, HARDING & BUCHANAN
Consulting Engineers
John L. Hayden — John H. Harding
Oscar J. Campia
Water Works—Sewerage
Civil—Mechanical
Electrical—Structural
836 Park Square Building, Boston, Mass.

CHARLES HAYDOCK
Consulting Engineer
Water Works and Sanitation
Industrial Wastes
Design, Construction, Operation and Management
Reports and Valuations
2314 Girard Trust Co. Bldg., Phila. 2, Pa.

C. W. Durham — H. H. Henningson — W. A. Richardson
HENNINGSON ENGINEERING CO.
Consulting Engineers since 1917 for more than 600 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage
Standard Oil Bldg. — Omaha 2, Nebraska

HITCHCOCK & ESTABROOK, INC.
Lester D. Lee, Associate
Consultants to Municipalities since 1920
WATER, SEWERAGE, PAVING, POWER PLANTS, AIRPORTS, PUBLIC BUILDINGS, SURVEYS and APPRAISALS
241 Sheridan Road — 521 Sexton Building
Menominee, Michigan — Minneapolis 15, Minnesota

Take advantage of the services of these outstanding consultants!

HORNER & SHIFRIN
Consulting Engineers
W. W. Horner S. W. Jens
H. Shifrin E. E. Bloss
V. C. Lischer
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

INDUSTRIAL WASTES CONSULTANTS
(A Guggenheim Subsidiary)
—INVESTIGATIONS AND REPORTS—
Offices and Laboratories
2266 No. Meridian, Indianapolis 8, Indiana
120 Broadway, New York 5, New York
Russell B. Moore - A. F. Neilson - Robert J. Theroux
(Memberships in ASCE, AWWA, AIMME, CSEWA, ACS)

JONES, HENRY & SCHOONMAKER
(Formerly Jones & Henry)
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. FT. LAUDERDALE, FLA

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design, Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

MORRIS KNOWLES, Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. Pittsburgh 22, Pa.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester 4, N. Y.

GEORGE B. MEBUS
Consulting Engineer
Water Supply Sewage Treatment
Industrial Waste Treatment
NORTHWESTERN NATIONAL BANK BUILDING
GLENSIDE, PA.

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airfields
Statler Building 111 Sutter St.
Boston 16 San Francisco 4

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
327 Franklin St., Buffalo, N. Y.
52 Vanderbilt Ave., New York, N. Y.

Parsons, Brinckerhoff, Hall & Macdonald
G. Gale Dixon, Associate
Engineers
Dams, Water Works, Sewerage
Airports, Bridges, Tunnels
Traffic & Transportation Reports, Highways
Subways, Foundations, Harbor Works, Valuations
Power Developments Industrial Buildings
51 BROADWAY, NEW YORK 6, N. Y.

BOYD E. PHELPS, INC.
Architects and Engineers
Water Supply and Purification
Sewerage and Sewage Treatment
Power Plants, Buildings, Investigations, Reports, Appraisals, Rate Studies
Indianapolis and Michigan City, Indiana

It pays to secure competent and experienced engineering advice!

MALCOLM PIRNIE ENGINEERS
Civil & Sanitary Engineers
MALCOLM PIRNIE — ERNEST W. WHITLOCK
ROBERT W. SAWYER — G. G. WERNER, Jr.
RICHARD HAHN
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 W. 43rd St. New York 18, N. Y.

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
1 Lee Place Paterson, 1, N. J.

THOMAS M. RIDDICK
Consulting Engineers and Chemists
Municipal and Industrial Water Purification, Sewage Treatment, Plant Supervision, Industrial Waste Treatment, Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. New York 55, N.Y.

RIPPLE AND HOWE
Consulting Engineers
O. J. RIPPLE — B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports.
426 Cooper Bldg. Denver 2, Colorado

RUSSELL and AXON
Consulting Engineers
Geo. S. Russell
Joe Williamson, Jr. — F. E. Wenger
Sewerage, Sewage Disposal, Water Supply, Water Purification, Power Plants, Appraisals, Rate Investigations, Reports, Plans, Specifications.
408 Olive St. — Municipal Airport
St. Louis 2, Mo. — Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of
Municipal Public Works &
Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

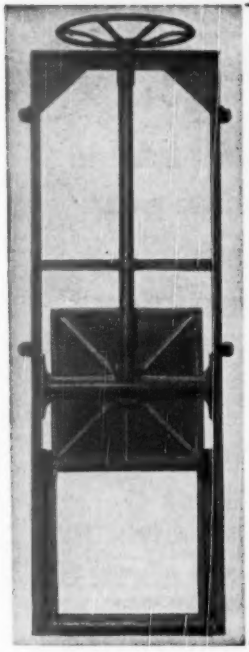
ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Mechanical Structural
Surveys Reports Appraisals
209 S. High St. Columbus 15, Ohio

WESTON & SAMPSON
Consulting Engineers
Water Supply, Water Purification,
Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans, Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

Take advantage of the services of these outstanding consultants!



SNOW GATES
for
SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular openings in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW IRRIGATION SUPPLY CO.

2437 East 24th Street **Los Angeles 54, Calif.**

SEWAGE PLANT EXPANSION ... WITHOUT BOND ISSUE!

It's easy and economical to convert most overloaded sewage plants to the BIO-CHEMICAL PROCESS. Increase the capacity of existing activated sludge plants as much as 100% . . . small conversion costs can be paid for out of operating savings.

Get the most . . . the best . . . for the smallest possible amount of the taxpayer's money with the BIO-CHEMICAL PROCESS.

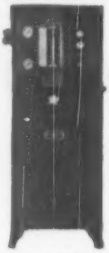
Write for further information.

the **B** *io-Chemical Process*

2266 North Meridian
Indianapolis 8, Indiana

120 Broadway
New York 5, New York

PROOF
OF
"STERELATOR EFFICIENCY"



NO JOB TOO LARGE

SEND US COPY OF SPECIFICATIONS

Actual Users—THE BEST PROOF OF ALL—
Prove our claims that Everson SterElators are
DEPENDABLE—SAFE—EFFICIENT
Easy to operate at LOW MAINTENANCE COST.
Everson SterElators METER-MIX-FEED
Chlorine gas accurately for all Water
or Sewage Sterilizing demands.
Furnished for Manual or Automatic operation.
Everson SterElators utilize a high Vacuum.
The Indicating FLOW METERS have a 10 to 1 ratio

SterElators by Everson

EVERSON MANUFACTURING CORPORATION
207 West Huron Street, Chicago 10, Illinois

Are You Interested in

Sewage and Industrial Waste Treatment?

If so, affiliate with

THE FEDERATION OF SEWAGE WORKS ASSOCIATIONS

•

For Particulars, Write

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
325 ILLINOIS BUILDING
CHAMPAIGN, ILL.

Please . . .

Copies of the following back numbers are badly needed:

1932—January, May	1935—March, May, July
1933—May, July	1941—May
1934—January	1944—January, March, May

Fifty cents plus postage will be paid for copies in good condition.

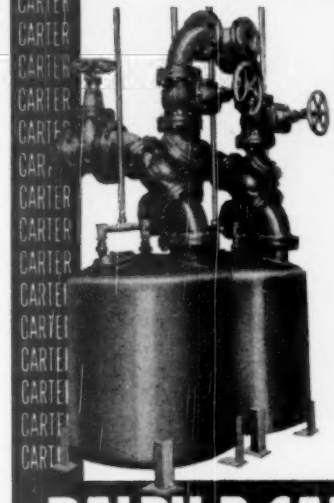
FEDERATION OF SEWAGE WORKS ASSNS.
325 Illinois Bldg. • Champaign, Ill.

THE RATHBUN-JONES
ENGINEERING CO., TOLEDO, OHIO

MANUFACTURERS OF
DIESEL ENGINES, GAS & DUAL FUEL ENGINES

CARTER'S PNEUMATIC SEWAGE EJECTOR

for continuous, trouble-free, economical handling of sewage lift problems



For day-in-and-day-out 100% sewage boosting you can't afford *not* to consider Carter's pneumatic sewage ejectors. They practically pay for themselves by elimination of the costly auxiliary screening equipment required with centrifugal pumps.

Solids and trash up to the size of the inlet and discharge valves are easily handled. No moving parts—no clogging or binding. Pots are either copper bearing, electrically-welded steel or cast iron—to your specifications. Hermetically sealed—completely eliminate stuffing box leaks and toxic gas dangers. Bronze mounted double disc gates and swing check valves. Rotary type air compressors of high volumetric efficiency. Fully automatic controls. Capacities—30 to 300 GPM.

Write Dept. S—give your specific waste problems, and we'll promptly furnish a detailed reply.

ROTARY DISTRIBUTORS • FLOATING & FIXED COVER DIGESTERS • ALTERNATING SIPHONS • PADDLE AERATORS • SLUDGE PUMPS • RAPID & SLOW MIXERS • PNEUMATIC EJECTORS • CIRCULAR COLLECTORS • FLOCCULATION EQUIPMENT • DIAPHRAGM PUMPS • SELF-PRIMING CENTRIFUGAL PUMPS • PLUNGER PRESSURE PUMPS

Exclusive franchises for representatives still open in some select territories. Write today!

184 Atlantic Street, Hackensack, N. J.

RALPH B. CARTER CO. HACKENSACK, NEW JERSEY

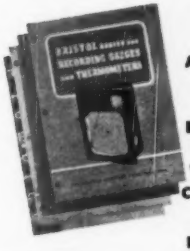
Don't delay in ordering your copy of

TWENTY-YEAR INDEX

SEWAGE WORKS JOURNAL—1928-1948

Price — $4.50

THE GARRARD PRESS CHAMPAIGN, ILL.



WHICH OF THESE BULLETINS DO *YOU* WANT—FOR LATEST FACTS ON RECORDING AND CONTROL INSTRUMENTS?

A. Pressure? Bulletin T835 describes Bristol Recording Gauges, Series 500, for measuring steam, water or gas pressure, from full vacuum to 10,000 psi.

B. Temperature? Bulletin T835 describes Bristol Recording Thermometers, Series 500, for measuring digester and dryer temperatures. Many new features.

C. Liquid Level? Bulletin L700 describes Bristol Liquid Level Recorders. Pressure, float and bubbler types.

D. pH? Bulletin pH1302 describes Bristol pH Controllers for treatment of sewage and industrial wastes.

BRISTOL *a complete line for sewage works*

Send coupon for bulletins you wish.

THE BRISTOL COMPANY
134 Bristol Road
Waterbury 20, Conn.
Please send bulletins circled.

A B C D

Name_____

Company_____

Address_____

City_____ State_____

PIPE CLEANING TOOLS AROUND the WORLD

OSLO, NORWAY — SINGAPORE, M. P.

*All this debris taken from 10" pipe. Section shows perfect job.

WATER LINES

*"Flexible" Power Bucket Machines, Power Drive, Rods and Tools make work easier in the Orient too.

SEWER LINES

"FLEXIBLES" IN OSLO AND SINGAPORE — AS WELL AS IN THE U. S. A.

"FLEXIBLE"

UNDERGROUND PIPE CLEANING CO. SEWER-ROD EQUIPMENT CO.

9059 VENICE BOULEVARD, LOS ANGELES 34, CALIFORNIA

141 W. Jackson Blvd. Chicago, Ill.
Francis Hankin Montreal & Toronto, Canada
147 Hillside Ter. Irving, N. J.
P. O. Box 165 Atlanta
P. O. Box 465 Memphis, Tenn.
801 E. Excelsoir Blvd. Hopkins, Minn.
29 Cardan Ave. Roslindale 31, Mass.
Box 167 Los Nietos, Calif.
41 Greenway St. Hamden, Conn.
3786 Durango Ave. Los Angeles 34, Calif.
709 House Bldg. Pittsburgh 22, Pa.
4455 S. E. 24th Ave. Portland 2, Ore.
351 W. Jefferson Blvd. Dallas, Texas

INDEX TO ADVERTISERS

	Page
American Concrete Pipe Association	6
Bio-Chemical Process	31
Bristol Company, The	23
Builders-Providence, Inc.	8
Carter Company, Ralph B.	15
Cast Iron Pipe Research Association	10
Chain Belt Company	9
Chicago Pump Company	1
Crane Company	3
Deer Company, The	20
Dresser Manufacturing Division	12
Economy Pumps, Inc.	14
Everson Manufacturing Corporation	33
Flexible Sewer-Rod Equipment Company	34
Foxboro Company, The	25
General American Transportation Corporation	24
General Chemical Division	30
Hamilton-Thomas Corporation	16
Infilco, Inc.	5
Koppers Company, Inc.	17
Link-Belt Company	13
Morse Bros. Machinery Company	11
Nichols Engineering and Research Corporation	29
Nordstrom Valve Division (Rockwell Manufacturing Company)	15
Pacific Flush Tank Company	21
Rathbun-Jones Engineering Company, The	32
Rockwell Manufacturing Company	19
Snow Irrigation Supply Co.	31
U. S. Pipe and Foundry Company	28
Wallace & Tiernan Company, Inc.	Back cover
Yeomans Brothers Company	4

DIRECTORY OF ENGINEERS, pp. 27–30

Albright & Friel, Inc.
Alvord, Burdick & Howson
Baker, Jr., Inc., Michael
Bantin, Nolan & Woodman
Bets, W. H. & L. D.
Black & Veatch
Bogert, Clinton L., Associates
Bowe, Albertson & Associates
Buck, Seifert and Jost
Burgess & Niple
Burns & McDonnell
Camp, Dresser and McKee
Capitol Engineering Corporation
Chester Engineers, The
Consoer, Townsend & Associates
Corson, Oscar
Damon & Foster
Dechant, Frederick H.
De Leuw, Cather & Company
Eckenfelder Associates, Inc.
Fay, Spofford & Thorndike
Fulton, Edward A.
Gannett Fleming Corddry & Carpenter, Inc.
Gilbert Associates, Inc.
Glace, Ivan M.
Goff, William A., Inc.
Greeley & Hansen
Havens and Emerson
Hayden, Harding & Buchanan
Haydock, Charles
Hennington Engineering Co.
Hickerson & Eastwood, Inc.
Horner & Shifrin
Industrial Waste Consultants
Jones, Henry & Schoonmaker
Leis & Holroyd
Kennedy, Clyde C.
Knowles, Morris, Inc.
Lozier, Wm. S., Company
Meiss, George B.
Metcalf & Eddy
Neweomer, Clarke & Veley, Inc.
Parsons, Brinckerhoff, Hall & Macdonald
Phelps, Boyd L., Inc.
Pirnie, Malcolm, Engineers
Purcell, Lee T.
Riddick, Thomas M.
Ripple and Howe
Russell and Axon
Smith and Gillespie
Stanley Engineering Company
Stilson, Alden E., & Associates
Weston & Sampson
Whitman & Howard
Whitman, Requardt & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

LANCASTER PRESS, INC., LANCASTER, PA.

WALLACE & TIERNAN
COMPANY, INC.